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CYTOPLASMIC ORGANS IN THE GERM CELLS AND SOMATIC CELLS OF TUBIFEX.

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CONTENTS.

(1) INTRODUCTION.

A large number of papers have been published in recent years on the cytoplasmic inclusions of animals of various groups, *i.e.*, mammals, insects, scorpions, molluscs, Ascidians, *Ascaris* and *Saccocirrus*, etc., but the study of these elements in various tissues of a typical Annĕlid, specially an Oligochaete worm, has been little attempted. The present work, which was begun at Cambridge, is an attempt to elucidate their nature in *Tubifex*, the common Tubificid found in Europe. The problematic function has been discussed by well-known workers among whom Hirschler, Duesberg, Meves, Faure Fremiet, Cowdry, Gatenby and Bowen may be mentioned. The modern trend of thought is that they take no part in the transmission of hereditary material in the same sense as the chromosomes do. In Tubifex this is borne out by the fact that the spermatozoon does not appear to carry mitochondria. Montogomery (58) found in the oviduct of the female *Peripatus* the spermatozoon entirely lacking the cytoplasmic lobes and mitochondria, therefore the discharge of mitochondria from the spermatozoon in this case is another illustration pointing to the same conclusion.

The spermatogenesis in Oligochaetes has been mainly studied in earthworms, but the previous workers having no recourse to the elaborate techniques that we have now, more or less overlooked the important study concerning the cytoplasmic structures. Depdolla (18) and E. Hesse (46), however, tried to follow their history though not in great detail.

It is remarkable that the Golgi elements or "batonettes" cover the head of the spermatozoon in *Tubifex*—a feature which has not been observed so far, in any other animal. In insects, *Saccocirrus*, molluscs and mammals the Golgi apparatus after giving rise to the acrosome occupies the tails of the sperms and is probably cast off as the Golgi remnant, taking

no part in fertilisation. In *Tubifex* there is no indication of the formation of the acrosome such as has been described by Gatenby in Lepidoptera (30), *Paludina* (32), and *Cavia* (35), Schitz in *Columbella* (65), Doncaster and Cannon in Louse (21) and Bowen in Hemiptera (4) and Lepidoptera (5). In Hemiptera the bulk of the acrosome is spread out along one side of the head and not located at the tip of the spermatozoon. In *Lepisma* (7) Bowen has shown that the acrosome instead of moving forward to lie at the apex of the sperm extends only further back along the tail occupying a position posterior to the sperm head. He uses the term acrosome, in the strict sense, to the material, which is contributed to the sperm by the Golgi apparatus. It is not the fact of the position of the acrosome in the sperm, which is the criterion for its identification, but it is the origin. In *Tubifex*, therefore, nearly whole of the Golgi apparatus of the spermatid surrounding the head of the ripe spermatozoon corresponds, in a broad sense, to the acrosome of the above-mentioned animals.

The abnormal or giant spermatids of a vermiform shape found in the spermatogenesis of *Tubifex* are interesting in the fact that they never develop into a mature spermatozoon consisting of the parts, head and tail, but on the other hand they appear to be of the nature of degeneration products. It appears likely that a number of spermatogonia become directly converted into these spermatids without undergoing a meiotic phase and division.

The mitochondria and Golgi elements are not only found in the nerve cells, but they also form an important constituent of the fibrous portion of the nervous tissue, into which they can be traced from the cells. They are found in almost all the cells of the body except in the advanced condition when functional activities have been exhausted or where degeneration or special modification has set in.

I have great pleasure to acknowledge my indebtedness to Mr. F. A. Potts for valuable suggestions in connection

with this work which was started a few months before I left Cambridge.

(2) MATERIAL AND TECHNIQUE.

The specimens of *Tubifex tubifex* were obtained from the river Cam and from the aquarium in the university laboratory at Cambridge. This species is easily obtained throughout the year with the genital organs at various stages of development. I usually obtained a very large number of sexual specimens from September to December and from March to May. I have also been able to get the sexually mature specimens in any other month of the year. The observation that this species is sexual throughout the year is of some importance when Dixon's remark, in her monograph on *Tubifex*, that October to December is the period when the sexual worms can be obtained, is taken into consideration.

I also cut sections of one worm of the genus *Ilyodrilus* which I happened to mix with *Tubifex tubifex.*

For a study of the mitochondria I fixed the worms in strong Flemming without acetic acid diluted by one half or in Champy's solution. The worms were fixed properly for vertical sections, therefore I never needed the help of a narcotic for straightening them beforehand. Iron-hæmatoxylin (long process) gives a delicate and sharp stain to the mitochondria. Altmann's acid fuchsin, Benda's Alizarine, and Champy Kull's acid fuchsin, Toluidin Blue and Aurantia methods gave good results; the latter proved by far the most successful.

After fixing the material for 24 hours in Flemming without acetic acid or in Champy's solution I removed the portion of the body containing about the first 25 segments and washed it under the tap, passed it through graded alcohols to cedarwood oil and imbedded in paraffin wax. The vertical sections,

about 2-4 μ thick, were cut and stained according to Champy Kull's method. So in this way the use of mordants, *i.e.*, acid acet., pyrolignosum rect., chromic acid and potassium bichromate, was done away with, and this saved five clear days. I found no difference between the stained sections as prepared according to the whole Champy Kull process and the shorter modified process as above stated.

According to Benda's method the mitochondria, the centriole and the axial filaments are sharply stained by the crystal violet. In order to see chromosomes, centriole, spindle and mitochondria in the same preparations the following fixitive was used for 24 hours, subsequently washed away for the same time under the tap and later followed by Champy Kull stain. The formula for the fixitive is—Formalin and saturated corrosive sublimate solution 10 c.c. each, 1% chromic acid 15 c.c. and 2% osmic acid 5 c.c. were mixed, and to this ·5—1 c.c. acetic acid was added just before using as advised for Flemming solution. The fixitive proved useful and served well all round.

For the study of Golgi apparatus Mann-Kopsch method was mainly employed. The worms were fixed in Mann's osmo-sublimate fluid for 2 hours. After fixation they were washed in two changes of distilled water for an hour and were transferred to 2% OsO_4 for 17 or 18 days. The vertical sections were cut and mounted directly or counterstained for mitochondria by Altmann's acid fuchsin method. I also used Da Fano's Cobalt Nitrate method, but this gave me much less satisfactory results.

(3) PREVIOUS WORK ON THE SPERMATOGENESIS IN OLIGOCHAETES.

The spermatogenesis of the earthworm has been studied by many workers. Bloomfield (2) was the first to give a clear

account in 1880 of the external features, which he studied from the living specimen or from glycerine preparations. The large nucleus of the primitive germ cell divides many times to form secondary nuclei which occupy a peripheral position around the central passive protoplasmic mass the blastophore, with a very little cytoplasm around them. These nuclei become the rod-like heads of the sperms. The blastophores probably atrophy and disappear after the spermatozoa leave them. The discovery of the "sperm blastophore" which he compares to the Sertoli cells of frog, forms the subject of his paper.

Calkins (10), 1894-95, studied the spermatogenesis of Lumbricus in more detail and arrived at the following results:

(1) A multinucleate cell is formed in the testis, which represents a group of the earliest spermatogonia. Each spermatogonium gives rise to several spermatozoa. The nuclei in the multinucleate cell arrange themselves around the periphery, and then "cytoplasmic cleavages" appear in between the nuclei as in the centrolecithal egg. The cleavages deepen until the nuclei are separated from the central blastophore by mere filaments. (2) The blastophore is not nucleated and cannot be compared with the Sertoli cells. It represents superfluous cytoplasm, the vital protoplasm being gathered around the nuclei. (3) The spermatocyte of the first order after a resting stage divides. The first division is the reducing division. (4) The head of the ripe spermatozoon is formed of the entire chromatin. The archoplasm (centrosphere) forms the middle piece. (5) The archoplasm is a constant element of the cell. In early stages of division it divides to form the poles of the karyokinetic spindle as well as the spindle fibres themselves. During the anaphase the spindle fibres are partly withdrawn into the archoplasm. The interzonal fibres probably form the Nebenkern, which finally disappears.

Bugnion and Popoff (8) in 1905 gave very good figures of the various aspects presented by the spermatogonia of Lumbricus. They in some cases show 1 or 2 nucleoli in the resting stage. The archoplasm, which Hesse after Meves calls idiosome, occupies a distal situation, while the procephalic corpuscle is proximally placed. The spermatogonia can multiply by mitosis and give rise to numerous cells attached to one another by thin stalks. In these bunches some cells are squeezed into masses, which become separated by rupture of the uniting stalks. These separated groups by further modification form the morulæ. This dissociation had already been referred to by Bloomfield. The spermatocytes I are not larger than the spermatogonia. The authors, however, did not study in detail the modification of the spermatid into the spermatozoon, but they found the giant sperms in addition to the ordinary ones in Lumbricus.

Depdolla (18) in 1906, leaving a great part of the account of the primary stages, has mainly studied the spermateleosis ("Die Histogenese der Spermatozoen") in detail. His conclusions are as follows:

(1) The nucleus of the spermatid undergoes a resting stage for a short time, during which its chromatin is densely condensed and surrounded by a vacuole filled with nuclear sap. It now grows; the chromatin gets loosened and wanders along the nuclear membrane. The spermatid grows fully till it attains the length of the sperm head and now once again the chromatin is condensed.

(2) The centrioles lie hidden among the mitochondrial grains, but they become visible during the resting phase of the spermatid. They are united by a connecting thread. The tail is inserted at the distal centriole. The proximal centriole grows outwards into a cone-shaped substance till it reaches the distal centriole. They both ultimately form by fusion the cylindrical central substance of the middle piece ("Mittelstück").

(3) The mitochondria are present in the spermatocytes; they surround circularly the equatorial plate of the mitosis. In the spermatid they are fused to form the mitochondrial substance which lies close to the caudal filament and the centrioles. After the complete growth of the proximal centriole the mitochondrial substance begins to surround the central substance of the middle piece and a small portion of the nucleus, around which it forms an envelope.

(4) In the young spermatid, which is still rounded, there lies a clear vesicle near the nucleus. The "Spitzenstück" or apical piece of the spermatozoon (acrosome) probably arises from this vesicle.

(5) When the spermatid elongates, there appears a strongly staining "Aussenkörper" which perhaps gives a different mitochondrial mass from the one already referred to.

(6) In addition to the large nucleated germ cells in the outer part of the testis there are also present small mysterious "Interstitielle Zellen," which perhaps by degeneration supply the neighbouring spermatogonia with the cytophore protoplasm before they are arranged to form a morula. The cytophore therefore is formed in the testis.

(7) About the end of the spermateleosis the blastophore breaks up after it shows vacuoles and colourless concretions. As it degenerates the ripe spermatozoa are liberated.

Depdolla gives the first account of the mitochondria, "Aussenkörper," centrioles and "Spitzenstück" (acrosome), which, from his description, arises from the "idiosome" of Meves or "archoplasm" of various authors. "Aussenkörper" is probably what is now known as the Golgi element.

Hesse (46) in 1909 gives a more detailed account of the spermatogenesis in *Lumbricus* and *Pheretima*. The spermatocytes of the first order are not larger than the spermatogonia from which they are derived. The reducing division is followed by a resting stage. In each division a part of the cytoplasm from the germ cells passes towards the centre of the

morula. This residual protoplasm without a nucleus constitutes the blastophore which, contrary to Depdolla's statement, is never nucleated. The archoplasm or centrosphere, which he calls idiosome, occupies the proximal position, *i.e.*, on the inner side of the nucleus towards the blastophore, while the centrioles with a clear mass, as seen in his figures, occupy the distal region, *i.e.*, on the outer side of the nucleus. He thus differs from Calkins, and Bugnion and Popoff and makes a confusion in considering the idiosome as a separate element from the archoplasm or centrosphere which, as is now well known, represents one and the same thing.

During spermateleosis the spermatid nucleus passes through a stage of "pseudo-metamerisation" and reaches a length greater than that of the head of the ripe spermatozoon, which it forms later by retraction. During this retraction the colourability of the chromatin changes totally. The chromatin is divided into two portions, a layer of outer basophile granules and the axial acidophile cylinder. Since the basophile granules disappear, it is the acidophile cylinder which constitutes the head of the ripe spermatozoon. The idiosome does not give the acrosome or "Spitzenstück" of the spermatozoon; it is placed at the base of the tail tangentially to the centrosomine rod ("baquette centrosomienne") and contributes with a large portion of the mitochondria to the formation of a curious transitory appendix described by Depdolla under the name of "Aussenkörper," which appears to be homologous to "Nebenkernorgan" described by Retzius in a large number of invertebrates. The "Aussenkörper" appears as a spherical vesicle with deeply-staining walls and a clear vacuole in the centre; sometimes there may be two spheres. It may have the form of a haltere, or an elongated rod. Along with the mitochondria it enters in the constitution of the middle piece and surrounds the axial centrosome rod. When the spermatozoa are ripe, the external zone of the blastophore being now of a very fluid nature allows them to detach easily.

Hatai (44) in 1899 gives an account of the origin of the sperm-blastophore in the Microdrili. The spermatogonia when fully mature drop from the testis in a large number and gradually swell up. The nucleus in each cell of the outer layer moves inwards towards the centre of the cluster and undergoes mitotic division, while the cells in the central part remain in the resting stage. After the peripheral cells have divided the central cells degenerate and become transformed into the "sperm blastophore." The daughter cells, produced by several divisions of the spermatocytes of the peripheral layer, are half the size of the mother cells and become the spermatids. The spermatids undergo repeated cell divisions producing an enormous number of new spermatids which finally become the ripe sperms, the tails of which all turn in one direction. The blastophore itself changes from spherical to an oblong form. In many cases several nuclei are scattered through the blastophore and these represent the remains of the cells which have not yet been changed into the homogeneous mass. His idea that the spermatophore in the spermatheca is a mass of sperms with the blastophore, which assumes a different shape on account of its passage through the sperm duct, is wrong as is now well known. His view of the origin of the blastophore corresponds with that of Bloomfield who regarded it as the homologue of Sertoli cells.

Dixon (19) in 1915 described the structure and development of the spermatozoa in *Tubifex*. The spermatogonia become multinucleate on leaving the testis; the nuclei when first formed are scattered through the cell and soon they become arranged regularly around the periphery. The central portion of the cell has no nucleus. Cleavage marks around the nuclei appear which deepen and separate the cells now formed, from the central cytoplasm which is the blastophore. Her description of the origin of the blastophore is exactly the same as that by Calkins. The spermatocytes surrounding the

blastophore, first a few in number, divide by karyokinesis, probably twice, so that the number of elements in a sperm morula is considerably increased. The spermatids are much smaller than the spermatocytes, and there is an appreciable increase in the size of the whole morula. The spermatids by a simple metamorphosis give rise to spermatozoa; the nucleus elongates considerably to form the filiform head. The middle piece is not very conspicuous and the distal extremity of the spermatid is much drawn out into a cytoplasmic tail. The spermatozoa when about to leave become much less regularly arranged and by degrees separate from the blastophore. She observed two kinds of sperms developing in the sperm sac. The spermatids giving rise to the giant sperms are much larger and less numerous; their arrangement on the blastophore is as irregular as that of the spermatocytes from which they are derived. The tail, in the beginning quite short, increases in length as the head becomes fully developed. These sperms are much longer than the normal ones; the head forms about half the whole structure and the tail is straight throughout.

For a critical examination of the above historical account we confine ourselves to two main points, the blastophore and the cytoplasmic inclusions.

(1). Bloomfield, Hattai and Depdolla consider that the blastophore may be nucleated. According to the first two authors it corresponds to the Sertoli cells. Hattai, however, states that, owing to the degeneration of the central cells of the morula, the blastophore is formed.

Calkins and Dixon observed that the spermatogonium becomes a multinucleate cell, in which the nuclei first irregularly arranged later assume a regular arrangement around the periphery. The cleavage marks around them convert a single cell into a group (morula) of many cells with a blastophore in the centre.

According to Bugnion and Popoff, and Hesse, specially the latter author, the spermatogonia separate from the testis

in masses or morulæ. The cells of a morula during each division pass a part of the cytoplasm towards the centre, which becomes the blastophore.

(2) The mitochondria, idiosome, centrioles, and "Aussenkörper" of Depdolla have been mentioned in various stages of spermatogenesis by Depdolla and Hesse. Calkins gives the first detailed account of the archoplasm. Though Hesse has tried to deal with the various cytoplasmic elements at some length, he has not been able to clear up, as he himself says, the nature of "Aussenkörper," which in places he has confused with the mitochondria. The "idiosome" of Meves was called by Calkins, and Bugnion and Popoff the "archoplasm," but the position it occupies in the spermatogonia and spermatocytes according to these authors is different from that referred to by Hesse, who puts it near the nucleus on the side opposite to the centrosphere and probably confuses it with something else, possibly mitochondria. In the spermatid, however, he shows it on the outer side at the base of the growing axial filament. "Dans les spermatocytes de 1er ordre l'idiozome est encore proximal (Fig. 2) mais dans les spermatocytes de 2^{e} ordre et dans les spermatides il est toujours distal." In view of the recent work on the Cytoplasmic Inclusions in the various invertebrates it appears obvious that the "Aussenkörper," closely connected with the idiosome and having essentially similar staining reactions during spermatogenesis as the mitochondria, is really what is now known as the "Golgi element," "acroblast" or "Golgi apparatus."

(4) SPERMATOGENESIS OF TUBIFEX.

(i) Spermatogonia.

The testis is attached to the posterior face of septum 9/10 by a narrow base or stalk near the ventral parietes and lies in the 10th segment one on each side of the ventral nerve cord. It is composed of a large number of spermatogonia—small

rounded cells with a large spherical nucleus in which the chromatin during the resting stage is distributed in the form of fine granules and the karyosome is surrounded by a clear space. Fig. 1 shows a part of the testis drawn from a Mann-Kopsch preparation; the spermatogonium here contains a single Golgi body in the form of a batonette lying on one side of the nucleus; in some of the cells the archoplasm is also found near the Golgi body. The cytoplasm in a spermatogonium forms a thin layer surrounding the nucleus. Except the Golgi element, which is stained deep black, the cells with the karyosome are stained yellow. The archoplasm is, however, distinguished by its lighter yellow appearance. Fig. 2 represents a few spermatogonia from the testis showing a large number of mitochondria in the form of fine granules lying in the thin layer of cytoplasm and placed more closely to the nucleus than the periphery. Fig. 3 shows a number of spermatogonia separated from the testis and lying freely in the sperm sac; the Golgi body in the form of a small dot is seen lying closely to the nucleus on one side. The archoplasm is also observed clearly in some of the cells. In some cells there are 2—4 black dots separately placed close to the nucleus as will be seen in Figs. 4 B and C. The rounded Golgi element may lie in the centre of the archoplasm (Figs. 4 A and C). Figs. 5 A—D show it during cell division; Fig. 5 D shows the metaphase in which nearly half of the Golgi apparatus in the form of slightly curved rods lies near each pole of the spindle. In the sperm sac several masses of spermatogonia, each consisting of 6—10 cells, are found. The cells in each mass lie close to one another but at this stage there is no indication of the formation of the sperm blastophore. The spermatogonia gradually become detached from the testis and drop down in the body cavity of the 10th segment from where they pass into the seminal vesicle, generally in bunches of 6—10 cells. They are not united with one another by stalks as in the earthworm according to Bugnion and Popoff, and Hesse,

but they are closely joined to one another. We have not observed anything like the multinucleate cell either in the testis or in the sperm sac, nor do we find any cleavages converting subsequently such multinucleate cell into a group of several cells as has been described by Calkins (10) in *Lumbricus*, and Dixon (19) in *Tubifex*; on the other hand, we agree with Hesse (46) that the cells are detached from the testis in groups, or they may form such groups immediately after detachment by active mitotic divisions, becoming soon after converted into morulae composed of spermatocytes of the first order. There is no doubt that multiplication of spermatogonia takes place by mitosis as several cells in the testis are observed in the form of mitotic figures. In the spermatogonia arranged in a morula the archoplasm with the Golgi elements is situated close to the nucleus on the outer or distal side and not on the proximal or inner side as Hesse (46) describes. As is already pointed out, he has confused the "idiozome" in these cells with some other body, because his Fig. 2 shows the centrioles with the clear archoplasmic mass (Idiozome) occupying a distal position. In *Pheretima*, however, he shows its position in the proximal region close to the centrioles in spermatogonia and spermatocytes I, while in spermatocytes II and spermatids he indicates it in the distal region.

Degenerate Spermatogonia.—A number of spermatogonia in the sperm sac lie isolated in a more or less degenerate and dilated condition. The cytoplasm in these cells is large in amount—a condition just opposite to what we find in the normal spermatogonia. The nucleus lies on one side and is much reduced in size; the cytoplasm is vacuolated, the vacuoles being filled with some fluid substance. Some such cells as seen in the Mann-Kopsch preparations contained the Golgi elements and showed various stages of degeneration. In the earliest stage of degeneration the cell does not differ much from the normal spermatogonium except in the fact that the cytoplasm

is somewhat vacuolar. The nucleus is large and cytoplasm small in amount. As the cell grows in size with the increase in the amount of cytoplasm, the nucleus gradually becomes reduced till one gets a very large cell with a small nucleus and large amount of cytoplasm (Fig. 6). The chromophility of the cytoplasm also lessens, while its vacuolar character gradually becomes prominent. The diameter of the largest cell of this kind is about 14μ while that of the normal spermatogonium only 6μ.

(ii) The Spermatocytes of the First Order and the Blastophore

Spermatocytes I can be distinguished from the spermatogonia by the presence of a small amount of cytoplasmic mass or blastophore on their inner side. These elements, as remarked by Bugnion and Popoff, and Hesse, are not larger than the spermatogonia which precede them, and are about 6—8μ in diameter. The blastophore is formed by the superfluous cytoplasm which flows on the inner side of the nucleus towards the centre of the morula forming a thin central cushion, as seen in Figs. 7 and 8. Fig. 7 shows a larger mass of cytoplasm accumulated on the inner side of the nucleus than on the outer side which forms a thin layer; the small mitochondria of a usual granular form are found in larger number on the inner side near the rudiment of the blastophore occupying mainly its periphery, while the central part is free from them. The nucleus like that of the spermatogonium forms the main bulk of the cell. The karyosome surrounded by a clear space is first visible at this stage, but soon after it disappears. The chromatin is arranged thickly in isolated masses on the linin and is stained deeply. The centrioles are clearly seen during mitotic division but there is no aster formed. No special attention has been paid to the changes in the nucleus, yet it may be mentioned that the chromosomes are large in numbers

and dot-like and that the plane of division of the cell is tangential to the radius of the blastophore, as has been previously recorded by Calkins (9) and Hesse (46).

The Golgi apparatus in spermatocyte I lies close to the outer side of the nucleus and is larger in size than that in the spermatogonium. Figs. 9 and 10 show it in the spermatogonium and spermatocyte I of *Ilyodrilus*. The Golgi bodies are usually fused to form a black quadrangular wall surrounding the archoplasm or centrosphere as seen in Mann-Kopsch preparations. There are also present sometimes besides the apparatus, 1—4 isolated Golgi bodies applied closely to the nuclear membrane; in some rare cells quite a large number, 5—12 of such bodies may be present.

(iii) The Spermatocytes of the Second Order.

With some difficulty this stage was obtained in a few specimens. The usual stages which one ordinarily comes across are the spermatogonia and the spermatids during spermateleosis. It appears that spermatocytes II rarely pass into a resting stage; but, on the other hand, soon after the division of spermatocytes I, they undergo repeated divisions usually twice to form the spermatids. The number of spermatids in a morula is very large, usually 60 or 80, and from a group of 6—10 spermatogonia a morula consisting of such a large number cannot be obtained by two divisions only. Hattai (44) remarks that the spermatids undergo repeated divisions producing an enormous number of new spermatids, but we believe that ordinarily the spermatids do not divide. It is, however, peculiar that more than two cell divisions occur during spermatogenesis.

Spermatocyte II is much smaller in size than spermatocyte I, its nucleus is also about half the size of that in the latter. Figs. 11 and 12 show these cells cut in the outer surface plane;

the Golgi apparatus of a quadrangular form occupies a distal or outward position to the nucleus to which it is closely apposed. The Golgi elements apparently in the form of rodlets or batonettes are joined in most cases end to end to form a quadrangular wall surrounding the central archoplasm. In the side view the Golgi bodies appear forming a rim around the outer end of the spermatocyte nucleus as seen in Figs. 13, 14 and 15. The Golgi rim, if one may call it so, surrounding the central archoplasm or centrosphere presents a characteristic appearance and is a conspicuous feature of spermatocytes II and spermatids in the Mann-Kopsch preparations. The refractile delicate cytoplasm around the nucleus is not seen clearly and very likely shrinks owing to long treatment with osmic acid. Fig. 16 shows a morula of complete spermatids containing a nucleus and the Golgi apparatus. The blastophore is much larger in spermatocyte II morula than that in spermatocyte I.

The mitochondrial grains of a very small size lie on the inner side of spermatocytes II in a regular manner around the periphery of the blastophore (Fig. 16). They also lie closely around the nucleus, though they are here not conspicuous. There lie irregularly distributed in the blastophore a large number of granules which take a slight toluidin blue stain according to the Champy-Kull method and slightly dark yellow colour in the Mann-Kopsch preparations. These granules of a chromatoid nature are very different from mitochondria ; they are also present in the blastophore of the spermatid morula. Though a fairly large number of mitochondria lie in connection with each spermatocyte II, they are much smaller in size and much less in number than those present in the growing oocytes and somatic cells.

The peculiar yolk granules described by Gatenby in the spermatocytes of *Saccocirrus* (36) are here respresented by the chromatoid granules in the blastophore which show nearly the same chemical reaction.

(iv) The Spermatids.

It is not easy to distinguish the newly-formed spermatids from spermatocytes II, though in many cases the presence of an axial filament projecting out of the outer end enables one to do so. The spermatids (Figs. 13, 14, and 15) are nearly of the same size as spermatocytes II and surround the central blastophore which may be elliptical in outline or stretched in various directions. The sperm sacs are generally filled with spermatid morulae, the commonest stages found during spermatogenesis. The morulae vary greatly in shape, which may be elongated, rectangular, elliptical or sometimes nearly spherical. The number of spermatids in a morula is very large, 40, 60, 80, or sometimes more in a section.

The spermatids are poor in cytoplasm which is hardly noticeable, and are regularly arranged around the blastophore to which they are attached by the proximal end. The newly-formed spermatid represented mainly by the nucleus undergoes a resting stage in which the karyosome lies nearer the proximal end, and the chromatin is distributed regularly in the form of fine granules. The thin hyaline layer of cytoplasm around it is not noticed in the Mann-Kopsch preparations. It is rounded in form and somewhat pointed at the distal end. The Golgi apparatus occupies the same position as in spermatocytes II; it is composed of the Golgi bodies united to form a quadrangular wall surrounding the clear archoplasmic mass (centrosphere) at the outer end of the spermatid, from the centre of which the axial filament passes out, as seen in Figs. 13 and 16. The Golgi rim at the distal or outer end presents the same characteristic appearance as described in the case of spermatocyte II.

The mitochondria are arranged in the form of a regular layer on the inner side of spermatids surrounding the blastophore; they, however, do not appear to be present all round the

nucleus. Besides there are also present in the blastophore chromatoid granules.

While the residual protoplasm forming the blastophore is free from mitochondria, the latter may be distinguished in the spermatid as very small granules lying in the proximal side. They are, however, so small that it is very difficult to recognise them. One may as a matter of fact consider them to be absent. In some cases the peripheral layer of the blastophore takes a slightly deeper stain than the remaining part and the mitochondria are not visible as discrete bodies. Their number in spermatids is much smaller than that in spermatogonia and the spermatocytes of the first order, hence the difficulty to see them at this stage.

The centriole lies at the distal end in the centre of the archoplasm at the base of the axial filament. It is stained red with the Champy-Kull, and black with iron hæmatoxylin; it was also clearly seen in preparations stained according to Benda's method. Only one centriole is present as indicated in Fig. 16; we have never been able to see two centrioles as described in the earthworm by Depdolla (18) and Hesse (46).

(v) Spermateleosis.

The metamorphosis of the spermatid into the spermatozoon is simple. The spermatids, conspicuous only by the nuclei, are first rounded in shape and slightly pointed at the distal end at which the centriole forms the base for the projecting axial filament. The karyosome is present and the chromatin in the form of small granules is distributed regularly. The cytoplasm around the nucleus is not easily noticed. The nucleus of the spermatid slightly elongates, assumes an oval form with the pointed distal end having the centriole and the axial filament, which has now increased in length. The karyosome soon after disappears and the chromatin granules at one or two places are fused to form a little mass. The spermatid nucleus

elongates further and now assumes the form of a more or less spindle-shaped rod pointed at either end as seen in Fig. 17 B. By still further elongation it finally attains the form of an elongated narrow filiform head of a little greater length than that of the ripe spermatozoon. When all these changes are going on in the spermatid still attached at its proximal end to the sperm blastophore, the axial filament also increases in length and finally the cytoplasm from the spermatid flows around it to form the tail which is attached just behind the nucleus at the centriole as its base.

As seen in preparations stained with iron hæmatoxylin, the chromatin during these stages undergoes a chemical change and becomes divided into two kinds of substances; the outer or peripheral in the form of granules surrounds the axial acidophile rod (Figs. 17 C and D). This chemical change in the nuclear substance has also been observed by the author during the spermateleosis of *Stylaria lacustris.* The chromatic substance in the form of granules collects on the inner surface of the membrane while the acidophile rod is, according to Bowen (7), "the clear, unstained, more or less pronounced nuclear vesicle." Meves (55) noticed this process in molluscs, Duesberg in fishes, Hesse (46) in earthworm and Bowen (7) in many insects. It appears to be of widespread occurrence. It is suggested by Bowen that by this refining process the chromatic material is separated from the other nuclear substances and that extrusion of some unnecessary nuclear material takes place resulting in the final condensation of the nuclear stuff and that the extrusion has actually been observed in a few cases.

The mitochondria do not appear to form any part of the changing spermatid, nor are they found in the fully developed spermatozoon; it may be that because they are more or less invisible in the spermatid, it is impossible to trace them during the spermateleosis, or it is likely that they are expelled with the blastophore when the spermatozoa are ripe. The

spermatid nucleus when fully developed into the filiform head of the spermatozoon still attached to the blastophore is $5{\cdot}4\mu$ long, while the mature spermatozoon such as lies just in front of the funnel has the head 4μ in length. Hence an appreciable reduction in the length of the head after the spermatozoon separates from the blastophore takes place by a slight contraction.

The spermatozoa when fully formed are first regularly arranged around the blastophore with the apical end buried slightly in its substance and the tail quite free; soon after before the sperms are detached, this arrangement is much less regular. The apical end of the spermatozoon after it separates hardly appears to be cytoplasmic or derived from the blastophore cytoplasm to which it was previously attached.

The fully mature spermatozoon consists of a head with a very small pointed apex and a tail. The apical end, though inconspicuous, corresponds in position to the acrosome of the sperm in other animals or "Spitzenstück" of Depdolla, but this is not homologous to the acrosome of insects, molluscs or mammals, which is derived in a special manner from the Golgi apparatus of the spermatid. The middle piece which is continuous with the head behind is not noticeable and contains only one centriole from which the tail arises. A neck region or the middle piece inserted between head and tail is not differentiated. Bowen (7) includes this region in the tail from which generally it cannot be distinguished.

(vi) The Fate of the Golgi Apparatus and the Mitochondria during Spermateleosis.

The position and structure of the Golgi apparatus in the newly-formed spermatid has been already described. It occupies the same position and form in the spermatid even

when it assumes an oval form; but after the nucleus elongates further, the Golgi bodies in the form of small granules or batonettes gradually travel forward on all sides from their former external (posterior) position till they completely cover the elongated head of the ripe spermatozoon, as Figs. 18, 19 and 20, drawn from the Mann-Kopsch preparations, will show. There may be seen a few very small uncovered spaces in between the Golgi elements but on the whole they form a more or less complete covering around the head. The small apical end in front of the head also seems to be covered in many cases. As regards the position of the archoplasm in the mature sperm, we believe that a part of it takes part in the formation of this Golgi cover though it is not visible. The Golgi apparatus of the spermatid in *Tubifex* thus forms mainly a covering around the head, that is, the acrosome—a feature which has not been observed in the spermatozoon of any other animal. The acrosome here is not formed as in insects, molluscs and mammals from the acrosomic vesicle which encloses darkly staining acrosomal granule. It is, however, interesting to point out that the Golgi apparatus in the spermatozoon of insects (4, 5 and 30), *Saccocirrus* (36) and mammals (35) is found in the form of rounded or angular bodies on the tail. In *Saccocirrus* Gatenby (36) even found these bodies at the tails of the ripe spermatozoa in the receptaculum seminis of a female. But in *Tubifex* the Golgi apparatus is completely used up in the formation of the acrosome and there is no trace of it left on any other part of the spermatozoon.

The mitochondria, as stated above, do not apparently form any part of the spermatozoon and this is a point which may throw some light on the question of the possible significance of these bodies with the transmission of hereditary material in the same sense as implied in the case of the chromosomes. The tail of the sperm throughout its length is cytoplasmic and we have failed to see any mitochondria taking part in its formation.

(vii) The Golgi Apparatus in the Spermatophores.

In order to trace the fate of the Golgi apparatus further than the spermatozoon stage, spermatophores in the spermathecae of the worms prepared according to the Mann-Kopsch method were examined. The part or zone of the spermatophore representing the united heads of the spermatozoa is stained deep black as is seen in Fig. 21, while the rest of the spermatophore representing the united tails of the sperms and the prostatic secretion is yellow, *i.e.*, remains unaffected by long osmic acid treatment. This clearly shows that the Golgi covering around the sperm heads, *i.e.*, the acrosome, goes unchanged even after the spermatozoa are cemented to form a spermatophore.

(viii) The Remains of the Blastophore.

In the sperm sac there are also found rounded or irregular masses without any cellular structure which obviously are the remains of the blastophore. In the Mann-Kopsch preparations two or several black patches are invariably noticed in these remains which probably in some cases represent the undetached sperm heads left with the blastophore. In preparations stained with iron hæmatoxylin the blastophore remains take in places a deep blue colour; sometimes the whole globular mass is deeply stained.

The blastophore in the spermatid morula during spermateleosis generally contains 1—3 large vacuoles which probably have something to do with the detachment of sperms when they are ripe.

(ix) The Eupyrene and Apyrene Spermatozoa in Tubifex.

Meves (55), Kuschakewitsch (51) and Gatenby (31 and 32) have given an account of the normal (Eupyrene) and

abnormal or giant (Apyrene) spermatozoa of some Prosobranch molluscs, where spermic dimorphism is a phenomenon of common occurrence. Hyman (49) has recently described their formation in *Fasciolaria* (Prosobranch mollusc). The abnormal spermatozoa have also been described by Meves and Gatenby (37) in Lepidoptera. Dixon (19) described the giant sperms and their formation in *Tubifex*, the existence of which was later doubted by Gatenby as is seen from his remark: "I do not wish my words to be taken as my final opinion as regards the dimorphism of the spermatozoa of *Tubifex rivulorum* but I feel sure that neither of the spermatozoa drawn in Miss Dixon's monograph are mature."

I have found in most of the preparations prepared according to various methods peculiar stages in the formation of the " atypic " sperms. Though my account markedly differs from that given by Dixon it establishes the fact that in *Tubifex* different stages in the formation of the atypical spermatozoa are a common occurrence. I, however, never succeeded in finding a fully formed giant sperm containing all the parts of a typical spermatozoon. The final stage in its development observed, consists of a very long body representing possibly the head of a normal spermatozoon ; the axial filament or tail was, however, never noticed (Figs. 22 E and F).

The abnormal spermatid in an early stage is broad at one end and pointed at the other, *i.e.*, the distal end of the normal spermatid (Fig. 22). The Golgi bodies are fused to form a deep black mass surrounding the pointed end ; in one spermatid the posterior end behind the Golgi bodies is produced into a thin narrow cytoplasmic filament. The region in front of the fused Golgi bodies represents the spermatid nucleus. At L is seen a portion of the archoplasm surrounded by the fused Golgi bodies. The spermatids about eight in number lie in a group without any sign of a blastophore ; each is 8—12μ in length and about 1-2μ in breadth, while the length of the normal spermatid at about this stage is 3-4μ.

Fig. 23 shows a number of giant spermatids which are more elongated and narrower in breadth than in the first stage. At the distal end there is a deeply stained margin surrounding the clear axial substance but no centriole and axial filament are to be seen. The spermatids are bluntly pointed at the proximal end which is quite free owing to the absence of the blastophore.

Fig. 24 C shows a more advanced stage during spermateleosis as drawn from the Mann-Kopsch preparation, where the length is increased further; here the Golgi elements in the form of small batonettes or granules surround nearly the whole of the spermatid nucleus. Fig. 24 E shows a very advanced stage; the spermatid now has a vermiform shape and is of very great length which is about 30—44μ, *i.e.*, about 5-6 times the length of the head of a normal spermatozoon. It has a sharply stained outline as seen in the preparations stained with iron-haematoxylin. No axial filament or the tail of the spermatozoon is present. The whole body seems to be equivalent to the head of a normal spermatozoon. The giant spermatids were sometimes found in a large number but they were never seen attached to a blastophore. I have not been able to find a giant spermatozoon developed from such a spermatid as described above and believe that the giant sperm consisting of the same parts as the normal spermatozoon is not formed. I always found in the sperm sac besides the giant spermatids typical spermatozoa in various stages of development; the typical spermatozoa were also found in a huge mass in front of the seminal funnel opening. The giant spermatids are usually much less common than the normal ones in the same specimen.

The giant spermatids are of much greater length, stouter than the head of a typical spermatozoon and have a sharp outline; they never reach the typical spermatozoon form consisting of a head, and a tail. As regards the staining reaction they take the nuclear stain and hence represent mainly

the nucleus surrounded by Golgi bodies in final stages; the axial filament or cytoplasmic tail has not been found in them.

Figs. 36, 37, 38 and 39 in Dixon's monograph (19) appear to be stages in the formation of typical spermatozoa and not giant sperms as Gatenby has pointed out already. The giant spermatozoa described by her are not very different from the normal spermatozoa, and there is nothing in her description like what I have described and shown in my figures as the giant spermatids.

There is no doubt that sometimes small variations in the size of spermatids ordinarily occur. Sometimes the nuclei in spermatid morula may be much smaller than those in spermatids of the ordinary sperm morula. Though the sperms developed from these small spermatids have not been observed, it is quite possible that the sperms of a somewhat shorter size than the usual sometimes are produced. But the giant spermatids described above are something very different, and it is noteworthy that they have no connection with the blastophore, which does not appear in their development.

The question now arises whether the giant spermatids are functional and if so what special purpose they serve.

Hertwig in 1903 thought that the "apyrene" spermatozoa by fertilising an egg might produce offspring of a different sex from an egg fertilised by a "eupyrene" sperm. But this cannot explain the condition in an Oligochaete where the sexes are not separated.

Many authors such as Reinke (64) believe that the "apyrene" sperms are unable to enter the egg.

Goldschmidt (41) in 1915 has shown by growing spermatocytes and spermatids of moths in artificial cultures outside the body that the development of the spermatozoon depends on the osmotic relations of the cells as controlled by the follicle membrane in which the cells are enclosed. The abnormal spermatozoa of moths and Prosobranch molluscs are produced by failure of the follicle membrane to provide the necessary

osmotic conditions for proper development. As certain follicles become abnormal at an early stage of the spermatocytes, all the cells in the follicles develop abnormally.

Gatenby (32 and 37), after criticising Goldschmidt's view, thinks that in Lepidoptera no importance can be attached to the atypical spermatozoa other than that of a degeneration product. According to him the spermatogenesis is the sum result of a number of forces, and that when these forces do not work in unison they produce abnormal spermatozoa, and probably this happens, when the condition is altered in certain cells of the testis. He has, however, shown in *Paludina vivipara* that atypic spermatogonia and spermatocytes have numerous fine granular mitochondria, while the typical cells possess a very few stout, rod-shaped mitochondria. The differentiation of cells in this case to produce dimorphic sperms takes place early. The main period of growth of the atypical cells is during spermateleosis. He believes that in *Paludina* both kinds of spermatozoa are functional and are therefore not homologous to those in Lepidoptera as Meves suggests.

Reinke's view (64) regarding the "apyrene" spermatozoa of *Strombus* that they serve as a source of nourishment or stimulation to the normal sperms also does not appear possible, because in a great majority of the Metazoa such dimorphism does not occur. Hyman (49) considers atypical spermiogenesis to be due to the loss of nuclear organisation and to the effect of its disintegration products upon the cytoplasm. Reinke, Kuschakewitch, Meves and Hyman have found that the spermatogenesis of atypical sperms is characterised by the irregular behaviour of meiotic phase. In *Strombus* there is hardly any meiotic phase and the spermatogonium is changed almost directly into a spermatid. Kuschakewitch found in *Vermetus* a very irregular meiotic phase, but no division and the spermatocyte became directly converted into a spermatid. In *Conus*, however, he noticed a single division. Each of the

secondary spermatocytes was atypical and became directly changed into a spermatid. Meves, however, in *Paludina* found the condition more typical. Two atypical divisions take place. *Fasciolaria* (Hyman) is more typical than *Paludina* in this respect.

In *Tubifex*, as the fully formed giant sperms like those in *Paludina* have not been observed, it seems very likely that the giant spermatids never reach the final spermatozoon stage, and are thus degenerate products in the same sense as those in Lepidoptera. Sometimes a number of spermatogonia of a larger size than the usual have been observed in the sperm sac and it appears probable that these give rise to the giant spermatids directly without undergoing any meiotic phase and division, but this is a point which still requires further work.

(5) THE OOGENESIS OF TUBIFEX.

Gatenby (36) has given an account of the oogenesis in *Saccocirrus*. The fully grown oocyte contains four kinds of grains: (*a*) Golgi elements, (*b*) mitochondria, (*c*) true yolk, and (*d*) nucleolar extrusions, which he has distinguished by various staining methods. His account of the nucleolar extrusions in the form of pyramidal granules applied to the nuclear membrane outside the nucleus is interesting, but nothing like it occurs in *Tubifex* though the nucleolus in the ovum which becomes converted into yolk breaks up. The changes in the Golgi apparatus of the growing oocytes of *Tubifex* are nearly similar to that in *Saccocirrus*, but the formation of yolk takes place differently. It is believed that in *Saccocirrus* the Golgi apparatus only forms the yolk.

Vishv Nath in *Lithobius* (60) and *Buthus* and *Euscorpius* (61) derives yolk from two sources:—fatty yolk from the Golgi apparatus as in *Saccocirrus* and the true yolk as

extrusions from the nucleoli. In *Palamnaeus* he derives it only from the Golgi apparatus.

(a) The Mitochondria.

In the young oogonia of *Saccocirrus* (36) and *Limnaea* (32) Gatenby did not find it possible to demonstrate mitochondria, but in *Tubifex* I always found them in the youngest oogonia of the ovary, such as occupy a position in the stalk near the place of attachment to the septum concerned. They are stained as usual red according to the Champy-Kull method and black or grey with iron-haematoxylin. Fig. 25 shows the young oogonium with a very large nucleus containing a nucleolus and a small amount of cytoplasm around. The cytoplasm, larger in amount on one side of the cell, shows minute mitochondrial granules, which lie more thickly nearer the nucleus than the periphery. One cannot distinguish in the mitochondrium at this stage the central substance from the outer chromophilic envelope.

As shown in Figs. 26, 28 and 29 the mitochondria are larger in size during the growth period of the oocyte; they have the form of small rounded granules composed of a central chromophobic material having little affinity for the usual stains enclosed in an envelope of chromophilic substance. Gatenby, however, denies the existence of the inner chromophobic part of the mitochondrium in the ova of Lepidoptera. The whole cytoplasm in the oocyte is surcharged with innumerable grains of about equal size which are evenly distributed in all parts.

(b) The Golgi Apparatus.

The Golgi apparatus is clearly seen in the young oogonia as well as the growing oocytes. In Fig. 27 are shown two oogonia, each of which contains the Golgi apparatus lying

on one side of the nucleus. In some oogonia besides one Golgi apparatus there is a minute Golgi element without any indication of the archoplasm, while in others only one Golgi apparatus occupying a "juxta-nuclear" excentric position is noticed. The position and form, therefore, in the youngest oogonia is similar to that in the spermatogonia. In Fig. 26, are shown two growing oocytes A and B. In A are shown several isolated slightly curved Golgi batonettes among the mitochondria; besides there are also present near the nuclear membrane several closely placed Golgi elements, in the process of fragmentation representing the original Golgi element, from which the pieces break off and pass into the cytoplasm. In the oocyte shown in Fig. 29, the Golgi apparatus forms a large nearly circular mass surrounding the nucleus; many isolated batonettes also with the archoplasm lie distributed in a fairly even manner in the egg cytoplasm among the mitochondria. In most cases the isolated Golgi fragments have a moon-shaped or semi-lunar form and contain the archoplasm in the concavity; sometimes they are only seen as rodlets without archoplasm. In the dense mass surrounding the nucleus no definite form is recognised on account of the fusion of these elements and the archoplasm is not visible.

It is obvious from the above account that the Golgi apparatus which is rudimentary in the early oögonium grows rapidly during the growth of the oocyte and also fragments into pieces. These fragments though they at first lie close to the nucleus where they may form a fused mass, soon after separate, and lie isolated in the egg cytoplasm among the mitochondria. Thus hundreds of these isolated miniature Golgi apparatus are found freely in the fully grown ovum. The isolated Golgi elements may have sometimes a triangular or quadrangular form surrounding the archoplasm. The circum-nuclear Golgi elements do not necessarily lie with the concave side towards the nuclear membrane, but on the other

hand generally opposite is the case. In the fully grown ovum the Golgi apparatus after having fully grown has completely broken up and most of the Golgi elements have now moved from their peri-nuclear position lying freely in the egg cytoplasm. Only a few batonettes with the archoplasm now surround the nucleus and their individuality is distinctly noticeable.

Every part of the oocyte cytoplasm is strewn with the Golgi elements in a fairly even manner and every one of these elements is derived by a process of growth and fission from the Golgi apparatus of the original oogonium.

The condition of the Golgi apparatus in the growing and fully grown ova differs remarkably from that in the spermatocytes, although in the young oogonia and spermatogonia it is very similar.

(c) The Formation of Yolk.

The formation of yolk described in Ascidian by Hirschler (47) is by two processes: (1) by a simple metamorphosis and enlargement of the mitochondrium; (2) by a secondary fusion of the Golgi elements with these swollen mitochondria to form a compound substance. According to him in *Ascaris* (48) the mitochondria occasionally swell up to form the large yolk granules but the Golgi apparatus does not generally become intimately associated with them.

According to Gatenby (39) in *Patella* the Golgi apparatus takes a great part in the formation of yolk spheres, but in *Limnaea* either the mitochondria or the ground cytoplasm are most active in this respect. In *Saccocirrus* (36) he has described two kinds of yolk, the nucleolar deutoplasm derived from the nucleolus and true yolk which is fatty in nature from the Golgi apparatus. Vishv Nath (60 and 61) also finds the same thing in *Lithobius* and *Buthus* and *Euscorpius*.

In Tubifex the yolk is formed in a different manner; here the egg becomes completely converted into it, the nucleus being only left sometimes as a residual or degenerate matter. Fig. 28 shows a part of the egg cytoplasm lying on one side of the nucleus in which the yolk is being formed. The mitochondria marked *m.* contains a central chromophobe material while the Golgi bodies *g.* lie as black rods or batonettes freely or are attached to the side of a mitochondrium; besides there are also seen many fused mitochondrial grains loaded with some material, and thus presenting a dense appearance. The yolk grains first are simply the modified mitochondria to which is added some inert substance of a lipoid nature in which there is no fat. Later the Golgi elements also join in their make up. The figure also indicates the presence of 6 small subspherical vesicles in the nucleolus which in the Mann-Kopsch appear black.

The egg cytoplasm, mitochondria and Golgi bodies have now all disappeared, having been converted into yolk discs. There is nothing left of the original ovum except the degenerating nucleus. The yolk discs are stained yellow with the Mann-Kopsch; they are much larger than the largest mitochondria which together with the Golgi bodies have taken a full share in their formation.

Many early oocytes when fully grown become completely converted into yolk discs. Whether the nucleolus takes part in the formation of the yolk is doubtful, but the nucleus in many cases is left behind in a degenerate condition.

(6) SOMATIC CELLS OF TUBIFEX.

The mitochondria and Golgi apparatus have been described in the various somatic cells of vertebrates and invertebrates, such as nerve cells, liver cells and epithelial cells of the alimentary canal.

The Golgi apparatus was first described in 1898 in the ganglion cells of vertebrates surrounding the nucleus by an

Italian observer, Golgi (42), after whom it is named. Cajal, a famous Spanish worker, also observed it independently about the same time in the nerve cells. These famous workers and their pupils in Italy and Spain demonstrated its structure by elaborate silver impregnation methods in the gland and various other tissue cells of vertebrates and invertebrates.

The mitochondria have been discovered in the germ cells of various animals by cytologists in the various countries during the last twenty-five years. They have also been described in the somatic cells of many vertebrates and invertebrates.

It is now well known that the cytoplasmic organs can be discovered easily in a cell if the modern technique suitable for their demonstration is properly employed.

(a) The Mitochondria and Golgi Apparatus in the Epithelial Cells of the Spermatheca, Intestine and Seminal Funnel.

The mitochondria are shown in Figs. 31, 33, 34, 35, 36 and 37. They are usually rounded granules occupying a space near the periphery of cell, leaving free the region around the nucleus. Fig. 37 shows the epithelial cells of the seminal funnel; the cilia arise from the basal granules near which the mitochondrial grains are clearly seen; mitochondria are also present in the distal part of the cell, but the space around the nucleus is mainly free from them. Fig. 35 shows the same condition in the epithelial cells of the gut in which also the mitochondria mainly occupy a peripheral position. In Fig. 31 the epithelial cells of the spermatheca are shown; the mitochondria on the inner side of the cell are nearly spherical in form, but those on the outer side of the nucleus are rod-shaped. The rodlike appearance is due to the fusion of several rounded granules. The mitochondrium in all these cells is composed of only chromophilic substance. The central chromophobic material as is present in the mitochondrium of a germ cell is absent.

In the septal gland cells the mitochondria of a granular form only lie in the acidophile cytoplasm, the basophile portion being altogether free from them. The Golgi bodies or dictyosomes as shown in Figs. 32—34 and 36 are very prominent in the epithelial cells. They surround the nucleus, to which they are closely applied. Their peri-nuclear position is clearly seen in Fig. 34 which is a surface view of the cells cut in a section. The batonettes are moon-shaped, *i.e.*, slightly curved; the concave or the convex side may be towards the nucleus. The archoplasm is not noticeable. In Fig. 32, which shows a section of the spermathecal duct, the epithelium is ciliated; the Golgi elements mainly lie on the inner side of the nucleus, and a few may be found surrounding it. The Golgi elements also surround the nucleus of the peritoneal cell. The point that the epithelium lining the spermathecal duct is ciliated was disputed by Vejdovsky. Dixon and Gatenby confirmed Nasse's observation about the presence of cilia. It is beyond doubt, as will be seen from the figures, that the epithelial cells possess cilia which though short are quite conspicuous.

Fig. 36 shows the Golgi rodlets in the epithelial cells of the gut occupying more or less a peri-nuclear position; they are mainly observed on the outer side of the nucleus. The archoplasm is not seen.

Fig. 38 represents the epithelial cells of the seminal funnel of *Ilyodrilus*. The Golgi bodies have the form of spherical grains, some of which are larger in size than the others; they lie in close vicinity of the nucleus occupying a peri-nuclear position.

It is clear that in the somatic cells the mitochondria do not lie near the nucleus, but they occupy a peripheral position. The Golgi elements in the form of batonettes or granules, on the other hand, are closely associated with the nucleus, which they surround. They do not occupy an excentric position as described in the somatic cells of some vertebrates and invertebrates. The archoplasm is not seen in the somatic cells.

(b) The Mitochondria and the Golgi Apparatus in the Nervous Tissue.

Fig. 39 shows a part of the ventral nerve cord drawn from the Champy-Kull preparation. The ganglion cells, usually small in size, contain a large number of small granules; the narrow end of the cell passes into the fibrous strand of the nerve cord, which is also filled with similar bodies of rounded or rod-like form. The mitochondria, therefore, are not only present in the cells, but they also occupy the whole of the fibrous strand. A similar appearance is presented by the mitochondria in the cerebral ganglion.

Fig. 40 is a part of the cerebral ganglion drawn from the Mann-Kopsch preparation. Each ganglion cell contains a large rounded nucleus with a nucleolus; around the nucleus mainly on the outer side are found a large number of closely placed small Golgi bodies of rounded form. From the cells the Golgi elements can be traced into the large fibrous part of the ganglion, in which many grains of much larger size are also conspicuous.

In the nervous tissue of *Tubifex* two kinds of cells are present as distinguished by their size; the cells of smaller size are larger in number and therefore easily found, but the cells of large size are much rarer. Fig. 41 shows a large nerve cell from the nerve cord. Outside the nucleus lies a large dense mass of grains or Golgi bodies. In the narrow part of the cell which lies inwards to the nucleus and passes into the fibrous strand, the Golgi bodies are much fewer in number and the cytoplasm here shows a fibrillar structure. The archoplasm is not present in the cells or the fibrous strand as in other somatic cells described before.

From the above account it will be clear that the mitochondria and the Golgi bodies are not only present in the cells but they are also found in large numbers throughout the length of the fibrous strand of the nerve cord, and the cerebral ganglion.

(7) GENERAL.

(a) Morphological Entity of Mitochondria and Golgi Bodies.

Attempts have been made to show that Golgi bodies and mitochondria are one and the same thing and that one is derived from the other. No good case of such origin has been made, but on the other hand their history during mitosis, spermatogenesis and oogenesis, and their nature and position in somatic cells shows that they are different structures which probably play a distinctly separate role in the cell phenomena. Faure-Fremiet (28) considered Golgi bodies to arise from a part of the mitochondria in the snail spermatocyte. Certain other observers also expressed the same view. Hirschler (47) clearly distinguished mitochondria from Golgi bodies in Ascidians, both of which he traced from the early germ cells. Duesberg (23) called Golgi bodies as yolk, otherwise his description corresponds to that of Hirschler.

According to many workers among whom Hirschler, Perroncito, Golgi, Cajal, Gatenby and Bowen are prominent, the Golgi apparatus has quite a separate entity and structure of its own. It is always associated with the nucleus and is composed of two parts—the archoplasm and Golgi elements. Its behaviour in oogenesis is very different from that in spermatogenesis. In *Tubifex* it is not only present in somatic cells, but it is also present in the fibrous strand of the ventral nerve cord and cerebral ganglion in the form of granules. Little is known about its origin. There is no evidence that it is derived from the nucleus or that it arises *de novo* in the cytoplasm: on the other hand, in all probability it arises from the pre-existing Golgi apparatus passing from one cell-generation to the next. In *Tubifex* the Golgi apparatus of the spermatid more or less completely becomes converted into the acrosome, surrounding the head of the spermatozoon, and is probably passed on to the next generation through the fertilised egg. In primordial germ cells the Golgi body is a discrete element

having a definite minimum size, but in spermatocytes and early spermatid stages its entity is not generally visible on account of these elements having united end to end to form a more or less regular layer around the archoplasm. In the oocyte Golgi bodies are evenly distributed throughout the cytoplasm and every one of them has been derived by a process of growth and fission from the Golgi apparatus of the oogonium.

The mitochondria generally lie in the peripheral part of somatic cells before much differentiation or degeneration has set in and have no close association with the nucleus unlike the Golgi apparatus. In the early germ cells, however, they lie nearer the nucleus than the peripheral part. Meves (55) and Gatenby (31 and 32) found them in a series of molluscs differentiated into an outer chromophil layer and a central chromophobe core. The same condition is found in germ cells of *Tubifex*, but in somatic cells they are quite homogeneous and do not show any such differentiation. Faure-Fremiet (28) and Regaud have shown that they are composed of lipoid and albuminous substances. Hyman (49) suggests, where such differentiation exists, the lipoid substance probably collects up at the surface forming the chromophil layer, and the core mostly made of albuminoid is the chromophobe part. Where there is no visible differentiation, it is assumed that the two substances are held in "physical union by absorption or inhibition." The origin of mitochondria has been a matter of great dispute. Some authors, such as Kuschakewitsch (51) and Gatenby (31) think that they are produced by the nucleus. The latter author, however, changes his opinion considering them to arise as the result of interaction between emanations from the nucleus and the cytoplasm. They arise *de novo* in each cell generation though some may be carried from one cell generation to the other. Meves (56) and Duesberg (23) claim that the mitochondria are self-perpetuating organs and that they have a continuous history from

one cell generation to another. Hyman (49) denies that formed material ever issues from the nucleus in *Fasciolaria*, nor he finds any transitional stages between mitochondria and other cell structures. He does not think that they arise by the action of the nucleus on the "unformed cytoplasm." In *Tubifex* there is no evidence that they are derived from the nucleus, but they appear to multiply and pass bodily from one cell generation to the next. Though it is not ordinarily possible to demonstrate how they multiply by fission in spermatogenesis, several workers have observed it in many animals in living or preserved tissues. Gatenby and Bhattacharya (40) have recently shown that the spermatocyte mitochondria can divide and bud during the growth stage. In oogenesis, however, they have been seen to multiply by fission at a rapid rate.

(b) Chemical Composition.

There seems to be little doubt that the mitochondria and Golgi bodies though distinct from each other in structure and origin are allied as regards their chemical composition. This is evident from the fact that in many animals in the male germ cells both kinds of elements take the same mitochondrial stains such as iron-hæmatoxylin, Altmann's acid fuchsin or Champy-Kull stain. Gatenby described the "batonettes" or his "acroblasts" along with the mitochondria by the above-mentioned methods in Lepidoptera (30) and Molluscs (32). The Golgi bodies were also described in the earthworm though they were confused with the mitochondria by Depdolla (18) and Hesse (46), who did not use the modern techniques for them such as the Kopsch, Mann-Kopsch, or Cajal and Da-Fano's silver impregnation methods. It is now well-known that according to the Mann-Kopsch technique Golgi elements and mitochondria both may be stained black if $Os\ O_4$ is used for a longer time than necessary to stain the Golgi bodies; in the case of mitochondria, however, the colour can be removed

afterwards by using turpentine. Acetic acid used in the fixitive dissolves away both the mitochondria and Golgi elements. All these microchemical reactions point to the conclusion that these cytoplasmic organs are akin in their chemical composition. The presence of a fat olein in the Golgi bodies probably gives them a black colour after long treatment with osmium tetroxide.

Faure-Frémiet (29) has extracted a lipin or phosphatide from desiccated Ascaris ovaries, but it is doubtful whether he extracted it from mitochondria alone. Gatenby (38) believes that mitochondria and Golgi bodies have a substratum of protoplasm with which lipin or fatty substances of closely similar composition are intimately associated. According to him when chrome fixation followed by iron-hæmatoxylin shows both these structures, the formol or chromic acid fixes and makes stainable the protoplasmic basis. Many workers regard them as similar to the plastids in plant cells, which grow and divide and are impregnated with some phosphatide or lipoid substance. It is very difficult to say anything about their chemical composition, but what is now known, though not much, is that some lipoid substance takes a great part in their make up.

(c) The Acrosome.

The term acrosome in its modern sense is applied to the part of the sperm which arises from the Golgi apparatus ("Golgi apparatus plus idiosome" of Bowen). The acrosome varies widely in size, shape and mode of attachment. It may have the form of an apical button as in some annelids and echinoderms, or that of a broad flattened cap as in mammals, but in all these cases it lies at the anterior end of the sperm. Doncaster in his text-book of cytology describes it as a pointed apical body, the function of which is "probably to help in perforating the surface of the eggs when the spermatozoon enters it." Waldayer (68) on account of its position at the anterior end and its shape pointed

(spitzenperforatorium), or like a broad cutting edge (schneideperforatorium), assigns to it a mechanical function of piercing or cutting through the egg surface. Bowen (7) does not consider it to be "an adventitious appendage, contrived at the last minute out of any available stuff, and plastered like a gimlet to the top of the head." According to him it arises in a definite manner through the activity of the Golgi apparatus and is a part and parcel of the scheme of spermateleosis. There are numerous cases in which it is not adapted as a boring or cutting instrument. In many sperms, for example Hemiptera, a great portion of the acrosome is not situated at the apex, but is spread out along one side of the head. In *Lepisma* he has shown that instead of moving forward to lie at the tip of the sperm it extends further back into the tail and occupies a position posterior to the sperm head. It is not the fact of the position of the acrosome which is the criterion for its identification, but it is the origin. The acrosome in *Tubifex*, where it forms a covering around the sperm head, is a clear example of the fact that it is primarily not an organ for the penetration of the sperm into the egg. I agree with Bowen that it represents a regular contribution by the Golgi apparatus to the sperm, the exact function of which is as yet unknown. The acrosome of *Tubifex* spermatozoon being derived directly from nearly the whole of Golgi apparatus shows a primitive condition in the evolutionary history of the acrosome of other animals where it arises in a complicated way from the acrosomic vesicle, which encloses a darkly staining acrosomal granule as described by Gatenby in Lepidoptera (30) and *Paludina* (32), and *Cavia* (35), Schitz in *Columbella* (65), Doncaster and Cannon in Louse (21) and Bowen in Hemiptera (4), Lepidoptera (5) and *Lepisma* (7).

(d) The Probable Function.

With regard to their function there are two main schools of thought. Benda (1), Meves (57) and Duesberg (23)

represent the Mitochondria Idioplasm hypothesis, according to which the mitochondria carry the hereditary characters of the cytoplasm—"les porteur des caractères hereditaires du cytoplasm" or "die protoplasmätische Verebungsubstanz," *i.e.*, "the chromosomes of the cytoplasm." In other words, they are equivalent to that part of the idioplasm, which is situated in the cytoplasm. Meves studied the behaviour of the mitochondria carried by the sperm of *Ascaris* and echinoderms during fertilisation and in the developing embryo. In *Ascaris* they were equally distributed to the blastomeres, but in echinoderms they all pass into one blastomere and there is no regularity about this distribution. From the facts of spermatogenesis, fertilisation and embryonic development it appears that the mitochondria of the sperm are not idioplasmic. Their absence in the sperm of *Tubifex* and *Peripatus* points also to the above conclusion.

The other school of thought of which Gatenby is one of the exponents attaches no such importance to the mitochondria and the Golgi apparatus on account of their varying behaviour during spermatogenesis, oogenesis and fertilisation in various groups of animals; on the other hand, there is ample evidence to show that they are in some way connected with cell metabolism. Gatenby believes that they have some function "either as the storers of energy-producing materials or the providers of such." In this connection it may be mentioned that their abundance in nerve cells and fibrous portion of the nervous system in *Tubifex* supports the above statement. The formation of tail sheath directly from the mitochondria in the sperm of *Saccocirrus* (36) and scorpions (40) shows, however, a somewhat different function probably that of giving strength or support to the sperm tail.

Doncaster (20) in his text-book summarises the views of the workers on this side and states that there is little evidence to show that the cytoplasmic bodies play a prominent part in the transmission of inherited characters and it seems more

probable that "their main function is nutritional and concerned with the rapid transformation of the spermatid into the spermatozoon. They are usually conspicuous in cells, which are about to undergo differentiation and some workers have regarded them as purely temporary structures produced by the physiological condition of the cell, perhaps as reserves of nutritive material. It seems to be established however that they have the power of division and propagation like the plastids of plant cells, and with our present very imperfect knowledge it seems best to regard them as living structures of the nature of cell organs, which may multiply and become conspicuous at times when rapid intracellular differentiation is about to take place."

Mitochondria may all enter into a sperm as in *Fasciolaria* (49), or a few may be sloughed off as in Opossum or about half may be lost as in pulmonates (31) or they may all be lost as in *Peripatus* (58) and *Tubifex.* A great portion of the Golgi apparatus after giving rise to the acrosome is also sloughed off in mammals, molluscs and insects, but in *Tubifex* it is completely used up in the formation of the acrosome. It seems, therefore, established that the behaviour of the mitochondria and Golgi apparatus is by no means so uniform and regular as that of the chromosomes and in the words of Gatenby (36) "as direct bearer of any important or precise factors of heredity, the Golgi body and mitochondria appear to be ruled out by their inexact and variable behaviour in the germ-cell cycle. The chromosomes and the chromosomes alone, fulfil the necessary conditions." The exact function of the cytoplasmic organs remains still unknown in spite of the great amount of work that has been done in recent years.

(8) SUMMARY.

Spermatogenesis.

(1) The testis is composed of a large number of spermatogonia of about the same size. Each spermatogonium contains

a thin layer of cytoplasm surrounding the nucleus. The mitochondria in the form of minute granules lie in the cytoplasm nearer the nucleus than the periphery. The Golgi apparatus mainly represented by the Golgi element is small and lies eccentrically at one side of the nucleus in close association with it.

(2) No multinucleate cell in the testis or in the sperm sac as described by Calkins or Dixon is formed in the course of formation of a sperm morula.

(3) The spermatogonia separate from the testis in groups. Each group becomes converted into a morula of spermatocytes (I).

(4) Some degenerate spermatogonia are met with in the sperm sac.

(5) Spermatocytes I and II pass inwards superfluous cytoplasm which flows towards the centre of the morula and forms the blastophore. The mitochondria mainly lie on the inner side of the spermatocytes forming the periphery of the blastophore.

(6) The chromosomes are large in number and dot-like. No aster is formed. The plane of division is tangential to the radius of the blastophore.

(7) The Golgi apparatus in spermatocytes I lies on the outer side of the nucleus, it is much larger than that in the spermatogonium. The Golgi bodies are fused to form a quadrangular wall surrounding the central archoplasm. There may be seen, besides the main apparatus, 1—4 Golgi bodies closely applied to the nuclear membrane.

(8) The usual stages found in the sperm sac are the spermatogonia and spermatid morulæ. Spermatocyte II morulæ are rarely seen.

(9) Spermatocytes I probably give rise to spermatids by more than two divisions. Spermatocytes II are much smaller than spermatocytes I. The Golgi bodies apparently in the form of rodlets are joined end to end forming a

quadrangular wall surrounding the archoplasm. The Golgi rim thus formed at the distal end of the spermatocytes and spermatids presents a characteristic appearance.

(10) The blastophore is much larger in spermatocyte II and spermatid morula than in spermatocyte I morula and contains a number of chromatoid granules.

(11) The mitochondria, which are prominent in the growing oocytes and various somatic cells, are practically inconspicuous during spermatogenesis. The layer of cytoplasm surrounding the spermatid nucleus is hyaline in appearance and altogether devoid of mitochondria.

(12) The number of spermatids in a morula is large, about 60—80. In a spermatid the centriole lies at the distal end in the centre of the archoplasmic mass at the base of the axial filament. There is only one centriole present.

(13) The spermatid metamorphoses into a spermatozoon by a simple process of elongation. During this process the axial filament increases in length. The chromatin undergoes a refining process becoming divided into two kinds of substances—the axial acidophile surrounded by a thin layer of peripheral basophile granules.

(14) The mitochondria apparently do not take part in the constitution of a spermatozoon.

(15) The spermatid nucleus when fully developed into the filiform head of the spermatozoon attached to the blastophore is slightly longer than that of the free spermatozoon, but an appreciable reduction in its length takes place by a slight contraction after it separates from the blastophore.

(16) The acrosome is a covering of minute Golgi bodies surrounding the head of the spermatozoon.

The Golgi apparatus during spermateleosis breaks up in small rodlets or granules, which move proximally to surround the metamorphosing nucleus, around which they form a Golgi covering. The formation and position of acrosome is thus remarkably different from that already known in other animals.

(17) The acrosome around the sperm heads goes unchanged even after the spermatozoa are united to form a spermatophore.

(18) The "Apyrene" spermatids in various stages of development are described, but the "Apyrene" spermatozoa have not been observed. The axial filament is absent but acrosome is present. They are different from the atypical or giant sperms described by Dixon. The question of the significance of the giant spermatids or sperms is discussed.

Oogenesis.

(1) The mitochondria and the Golgi apparatus are similar in position and shape in the primitive oogonia and spermatogonia.

(2) In the growing oocyte the mitochondria, Golgi apparatus and cytoplasm increase in bulk. The whole cytoplasm is filled with innumerable mitochondrial grains. The Golgi elements fused to form a dense mass lie around the nucleus, besides there are also found a large number of isolated batonettes distributed evenly in the cytoplasm. In the fully mature ovum they do not form a fused mass around the nucleus but lie isolated. The rudimentary Golgi apparatus of the oogonium thus grows very much with the growth of the cell and by a process of fragmentation forms rodlets, which separate from their perinuclear position and become distributed throughout the cytoplasm.

(3) Many complete ova are converted into yolk, their nuclei being sometimes left as degenerate products. The mitochondria and the cytoplasm become loaded with some food substance and after fusing with the Golgi elements become converted into yolk discs. The yolk discs do not contain any fat.

Somatic Cells.

(1) The mitochondria and Golgi apparatus are described in the spermathecal epithelial cells, epithelial cells

of the alimentary canal and seminal funnel, and nervous tissue.

(2) The Golgi elements occupy a perinuclear position. Archoplasm is not noticed in the somatic cells.

(3) The mitochondria occupy a peripheral position in the cell and do not contain a central chromophobe substance.

(4) The Golgi elements have generally the form of batonettes, but they may have a granular form.

(5) The mitochondria and Golgi elements are not only found in the nerve cells, but they are also present in large numbers throughout the length of the fibrous portion of the nervous tissue.

General.

(*a*) Morphological entity of the mitochondria and Golgi bodies.

(*b*) Chemical composition.

(*c*) The acrosome.

(*d*) The probable function.

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(10) EXPLANATION OF PLATES.

Explanation of Lettering

a, Archoplasm ; a.f., axial filament ; bl., blastophore ; b.v., blood-vessel ; c., cilia ; c.p., clear cytoplasm ; ce., centriole ; c.g., chromatoid granules ; f., fibrous portion of nervous tissue ; f.p., food particles ; g., Golgi body ; g.s., Golgi bodies around fused spermatozoa ; k., karyosome ; m., mitochondria ; m.m., changed mitochondria ; m.l., muscle layer ; n., nucleus ; p., peritoneal layer ; r.b., rudiment

FIG 1

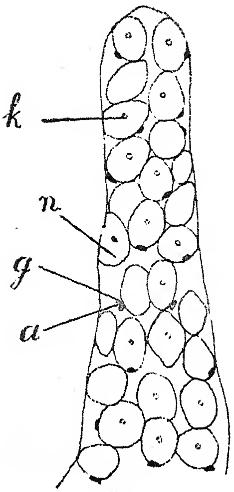


FIG 2

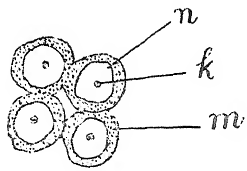


FIG 3

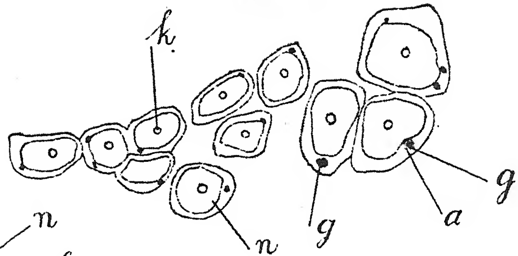


FIG 4A

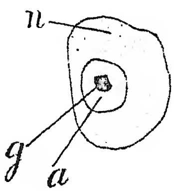


FIG 4B

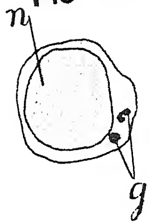


FIG 4C

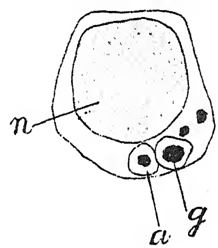


FIG 5A

FIG 5B

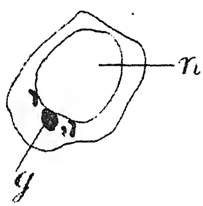


FIG 5C

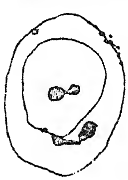


FIG 5D

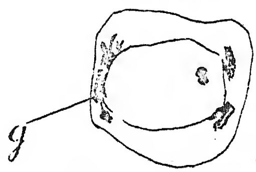


FIG 6

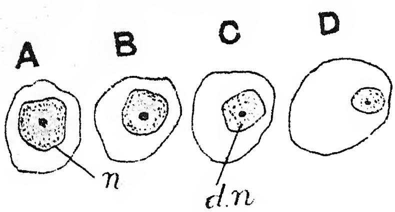


FIG 7

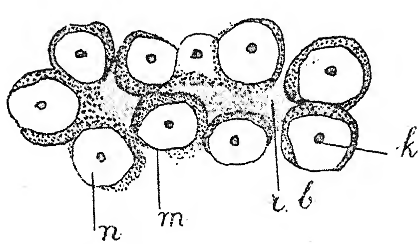


FIG 8

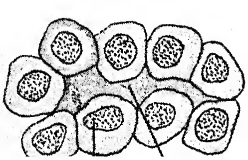
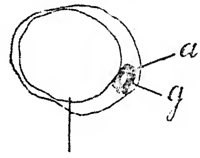


FIG 9



of blastophore ; t., tail of the spermatozoon ; t.s., fused tails of spermatozoa ; v., vacuole.

TECHNIQUES USED

M.K., Mann-Kopsch Method.

F.W.A., Flemming without Acetic acid, Iron-hæmatoxylin stain.

C.K., Champy-Kull Method.

B.C.H., Bouin's Corrosive-picro-formol-iron-hæmatoxylin Method.

M.K.C.K., Mann-Kopsch, Champy-Kull Method.

Fig. 1. Part of the testis. Spermatogonia with Golgi Apparatus excentrically placed are seen. M.K.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 2. Spermatogonia in the testis showing mitochondria. F.W.A.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 3. Spermatogonia in the sperm sac showing Golgi Apparatus. M.K.
Zeiss E. 12. O., Oil imm., 1/12."

Figs. 4A, B and C. Spermatogonia showing variation in the form of Golgi apparatus. The Golgi body lies in the centre of the archoplasm in A and C. 4A shows the Golgi apparatus in surface view. M. K.
Zeiss E. 18. O., Oil imm., 1/12."

Figs. 5A—D. Spermatogonia showing the Golgi apparatus. The Golgi apparatus has increased in size. D shows it in a condition of division ("dictyokinises"). M.K.
Zeiss E. 18. O., Oil imm., 1/12."

Figs. 6A—D. Spermatogonia in various stages of degeneration. Fig. D shows a very degenerate condition. Diagrammatic.

Fig. 7. Spermatocytes (I) in a morula. Beginning of the formation of blastophore. Mitochondria are seen in the form of granules. F.W.A.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 8. Spermatocytes I morula. B. C. H.
Zeiss E. 8. O., Oil imm., 1/12."

Fig. 9. Spermatogonium of Ilyodrilus. M. K.
Zeiss E. 18. O., Oil imm., 1/12."

Figs. 10A—C. Spermatocytes (I) of Ilyodrilus. Golgi apparatus occupies an excentric position. Besides the apparatus one or two small Golgi granules are present close to the nuclear membrane. M.K.
Zeiss E. 18. O., Oil imm., 1/12."

Fig. 11. Spermatocytes II showing Golgi apparatus in a surface view. M.K.

Zeiss E. 18. O., Oil imm., 1/12."

Fig. 12. Spermatocytes II morula showing Golgi apparatus at the outer or distal end of the cells, which is seen in surface view. M.K.

Zeiss E. 4. O., Oil imm., 1/12."

Fig. 13. Spermatid morula seen in side view. Golgi apparatus and axial filaments are seen. M.K.

Zeiss E. 8. O., Oil imm., 1/12."

Fig. 14. Spermatid morula. The cells are seen in the side view with Golgi apparatus at the outer end. The blastophore has two large vacuoles. M.K.

Zeiss E. 18. O., Oil imm., 1/12."

Fig. 15. Spermatids showing the Golgi apparatus in side view. M.K.

Zeiss E. 4. O., Oil imm., 1/12."

Fig. 16. Spermatid morula showing Golgi apparatus, centriole, axial filament and mitochondria. Semi-diagrammatic.

Fig. 17. Stages in spermateleosis. Semi-diagrammatic.

Fig. 18. Metamorphosing spermatids. The nucleus is elongated and surrounded by small Golgi granules or batonettes, which form a cover (Golgi cover) around it. Axial filament is also much elongated. M.K.

Zeiss E. 12. O., Oil imm., 1/12."

Fig. 19. Fully formed spermatozoa showing the Golgi cover or acrosome around the head. M.K.

Zeiss E. 12. O., Oil imm., 1/12."

Fig. 20. Spermatozoon showing the acrosome. Semi-diagrammatic.

Fig. 21. Spermatophores in sections. The region representing the fused heads of the spermatozoa is stained deep black with the Mann-Kopsch on account of the Golgi cover around. M.K.

Zeiss E. 4. O., Oil imm., 1/12."

Fig. 22. Giant spermatids. Early stage showing Golgi bodies. M.K.

Zeiss E. 18. O., Oil imm. 1/12."

Fig. 23. Giant spermatids. More advanced stage. The Golgi bodies surround the distal end. M.K.

Zeiss E. 4. O., Oil imm., 1/12."

Fig 10 A

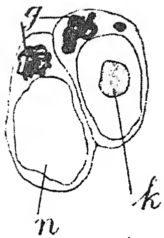


Fig 10 B

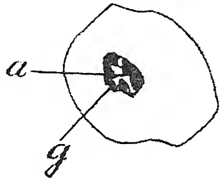


Fig 10 C

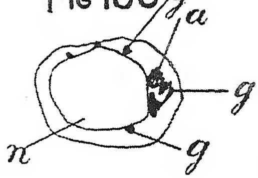


Fig 11

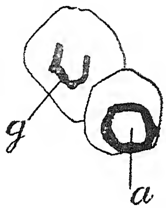


Fig 12

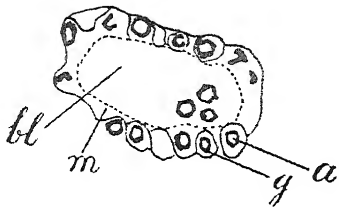


Fig 13

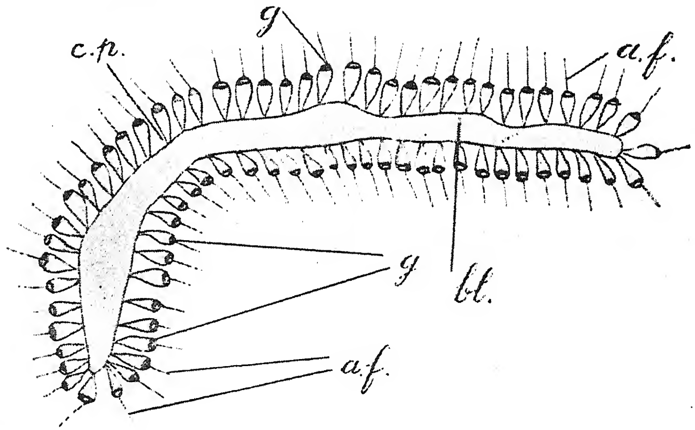


Fig 14

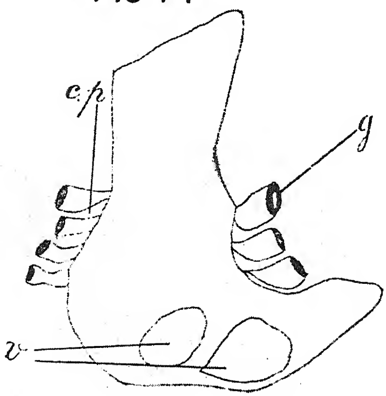


Fig 15

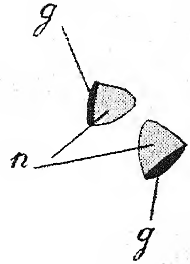


FIG 16

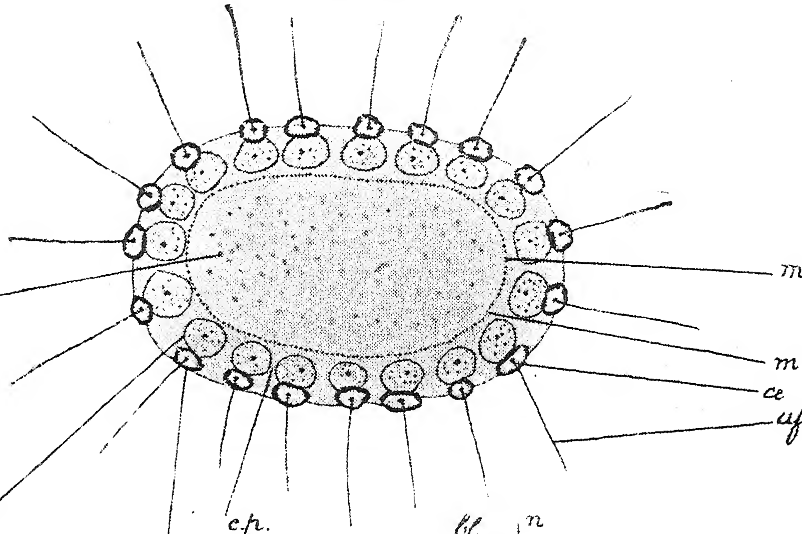
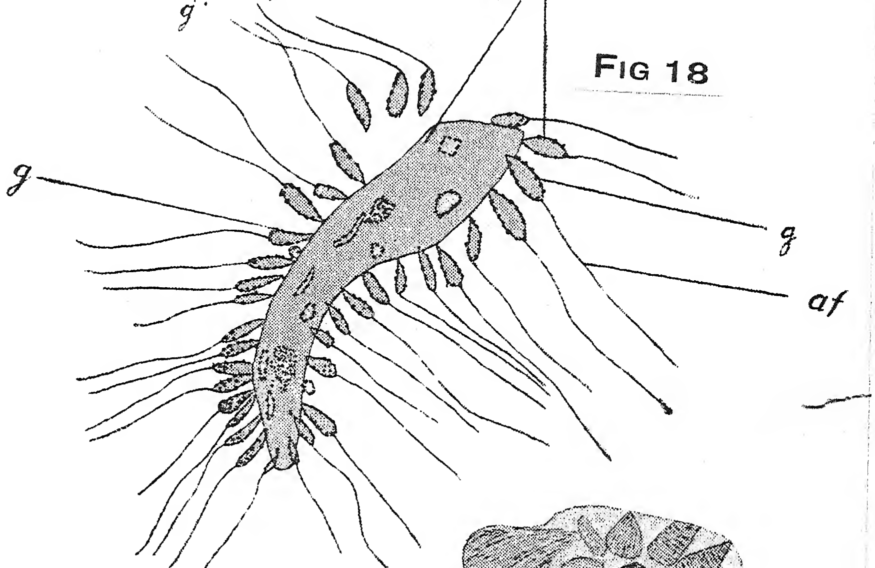


FIG 18



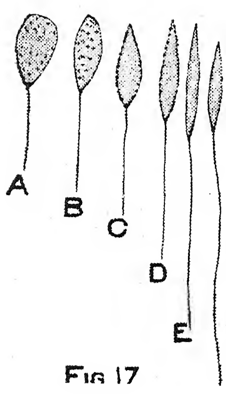
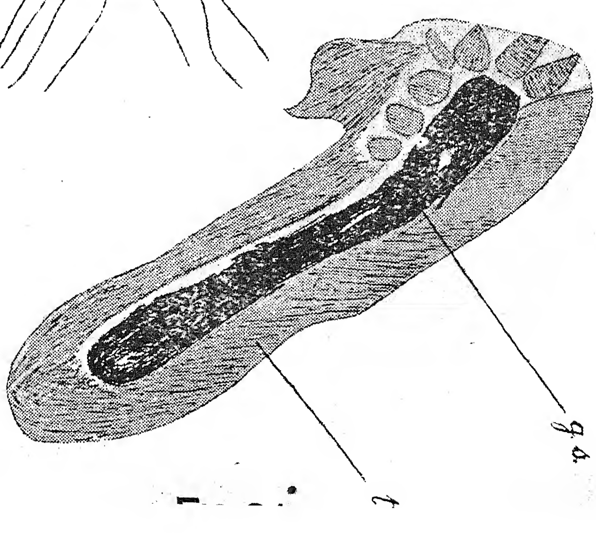


FIG 17



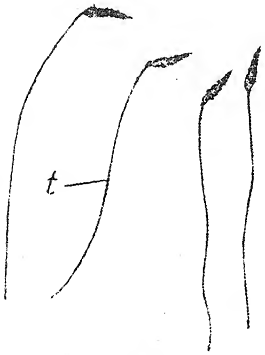


Fig 19

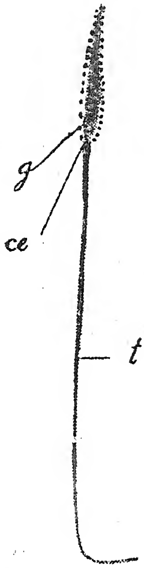


Fig 20

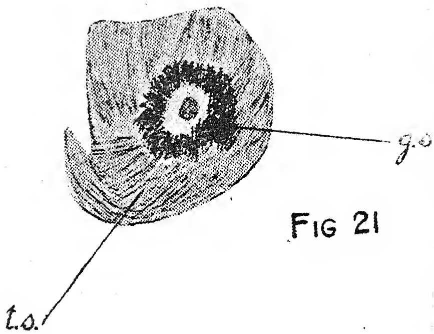


Fig 21

Fig 22

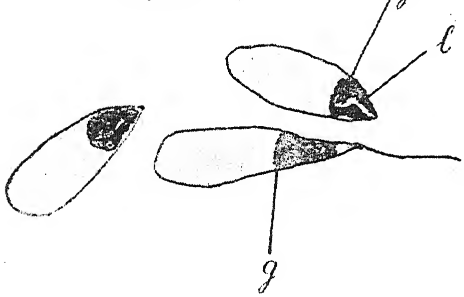


Fig 23

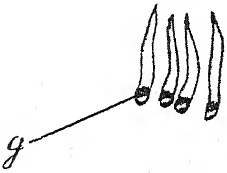


Fig 24

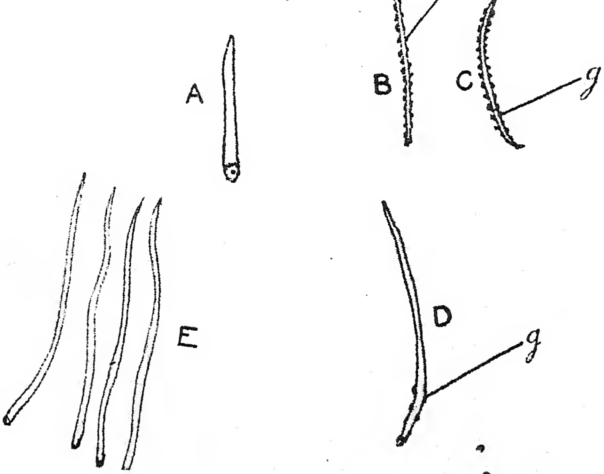


Fig 25

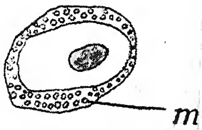


Fig 26

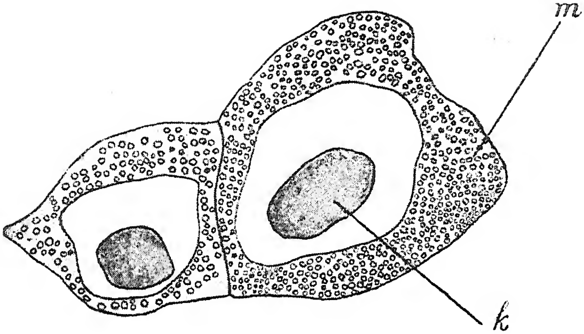


Fig 27

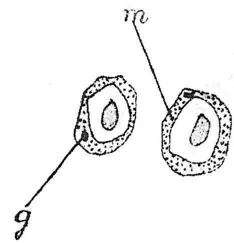


Fig 28

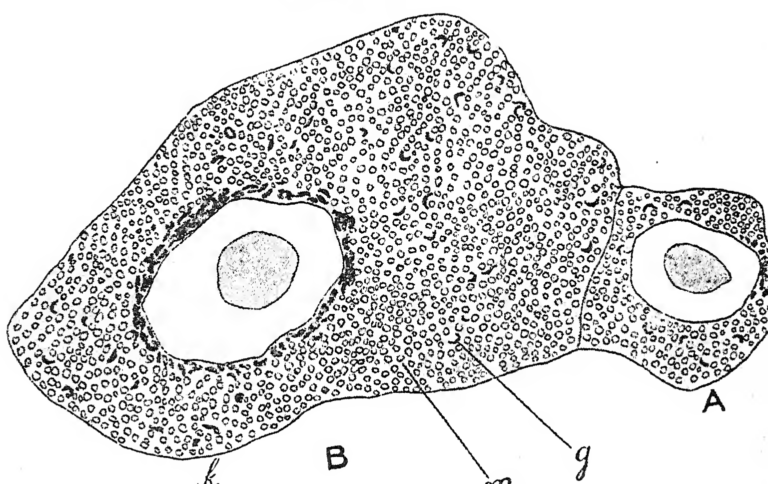


Fig 29

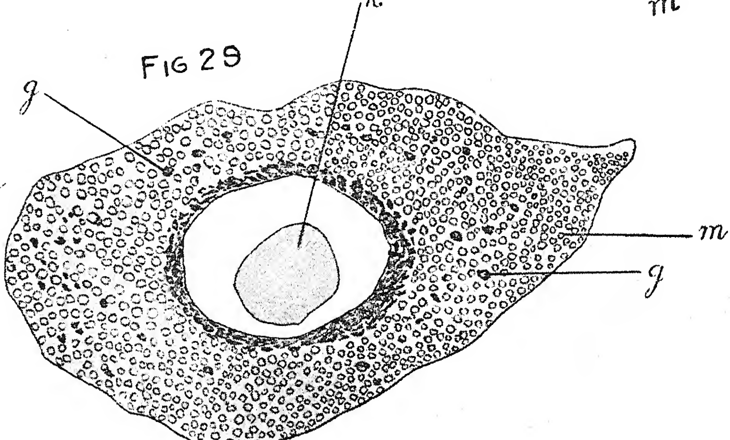


Fig 30

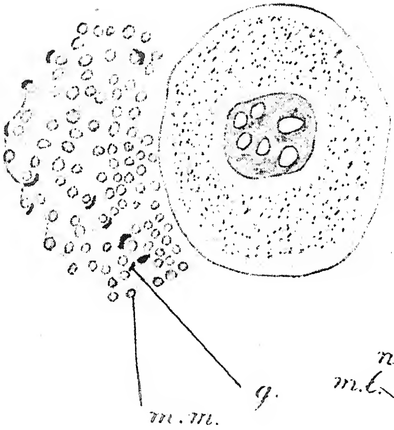
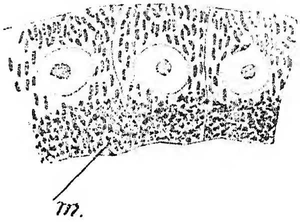


Fig 31



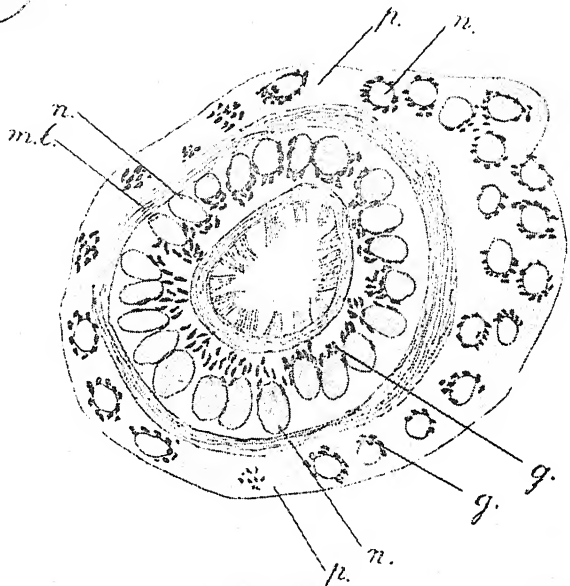
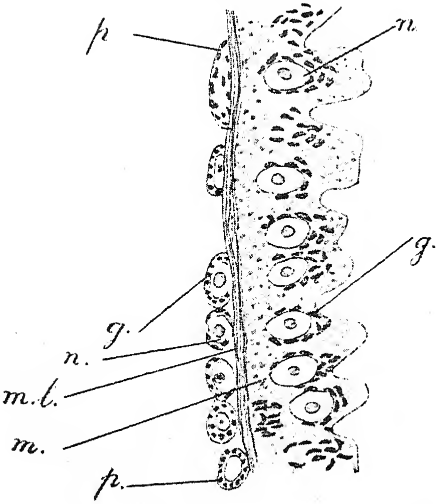


Fig 32

Fig 33



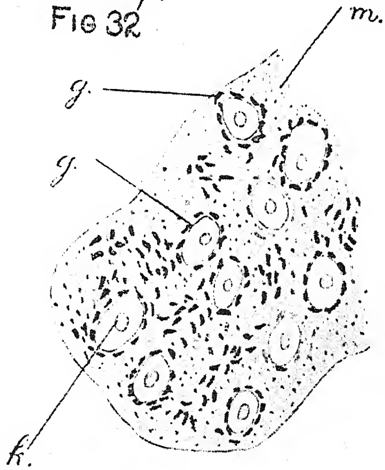


Fig 34

FIG. 35

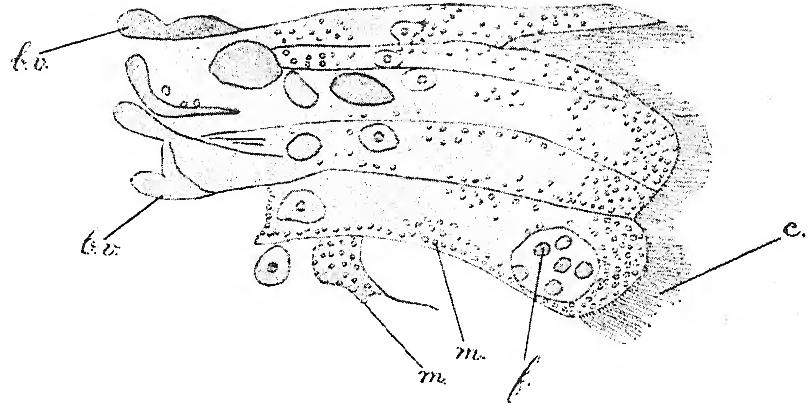


FIG 36

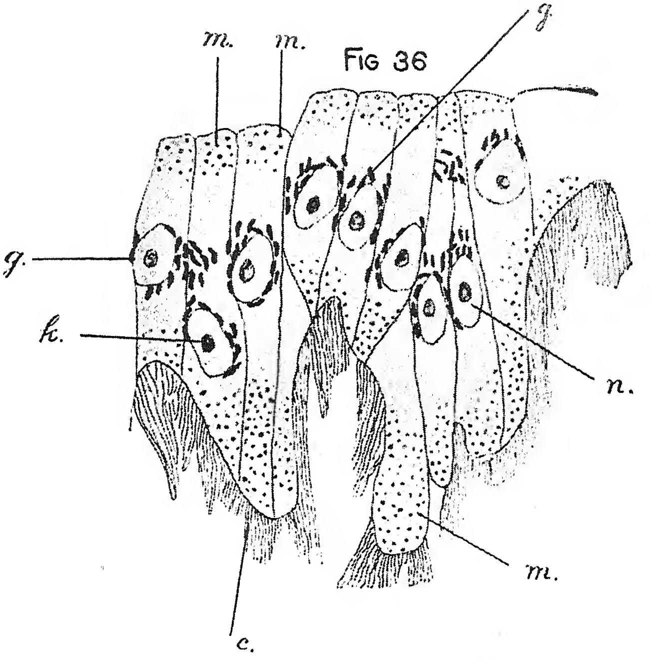
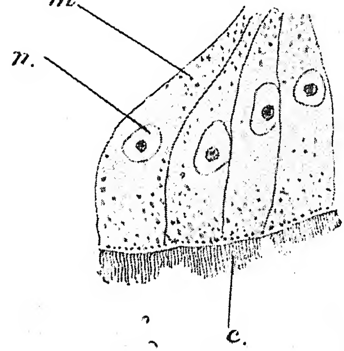


FIG 37



Figs. 24A—E. Giant spermatids. Final stages during spermateleosis Figs. A, D and E—B.C. H. Figs. B and C. M.K.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 25. Oogonium from the ovary. F. W. A.
Zeiss E. 12. O., Oil imm., 1/12."

Fig. 26. Two young oocytes showing mitochondria, C. K.
Zeiss E. 12. O., Oil imm., 1/12."

Fig. 27. Oogonia showing Golgi apparatus. M.K.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 28. Growing oocyte showing Golgi elements and Mitochondria. M. K. C. K.
Zeiss E. 12. O., Oil imm., 1/12."

Fig. 29. The same. M. K. C. K.
Zeiss E. 12. O., Oil imm., 1/12."

Fig. 30. A part of the mitochondria and Golgi bodies on one side of the nucleus is drawn to show the early stage in the formation of yolk. The nucleolus shows inside spherical vesicles. M. K. C. K.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 31. Epithelial cells of the spermatheca showing mitochondria. F. W. A.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 32. Section of the spermathecal duct showing Golgi elements. M. K.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 33. Section through the wall of the ampulla. The cells show mitochondria and Golgi bodies. M. K.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 34. Section through the wall of the ampulla showing the surface view. Golgi elements surround the nucleus. M. K.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 35. Epithelial cells of the gut showing the mitochondria. C. K.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 36. Epithelial cells of the gut showing Golgi elements and Mitochondria. M. K. C. K.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 37. Epithelial cells of the Seminal funnel showing mitochondria. F. W. A.
Zeiss E. 4. O., Oil imm., 1/12."

Fig. 38. Epithelial cells of the Seminal funnel of Ilyorilus showing Golgi bodies. M. K.

Zeiss E. 4. O., Oil imm., 1/12."

Fig. 39. Section through a part of the ventral nerve cord. The mitochondria are not only present in the cells, but they are also present in the fibrous strand of the cord. C. K.

Zeiss E. 4. O., Oil imm., 1/12."

Fig. 40. Section through the cerebral ganglion showing Golgi bodies. M. K.

Zeiss E. 4. O., Oil imm., 1/12."

Fig. 41. A large (giant) ganglion cell from the nerve cord showing Golgi bodies. M. K.

Zeiss E. 12. O., Oil imm., 1/12."

Fig 38

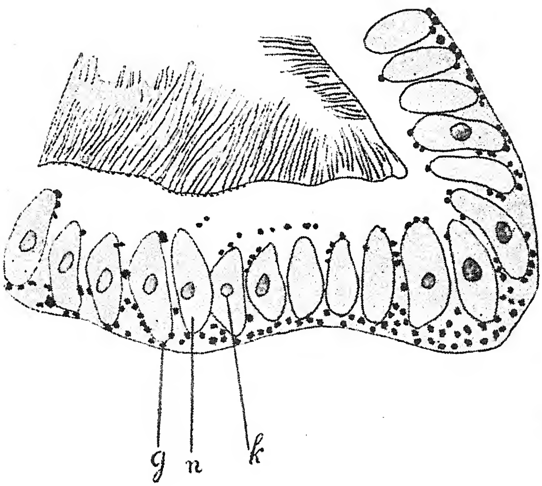
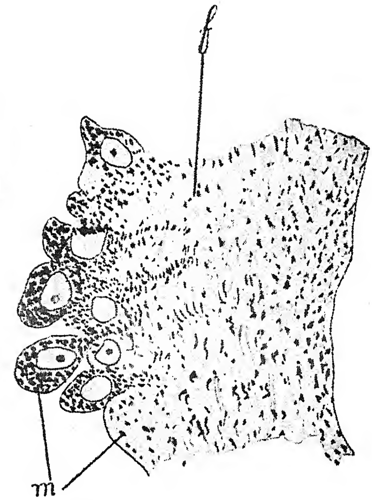


Fig 39



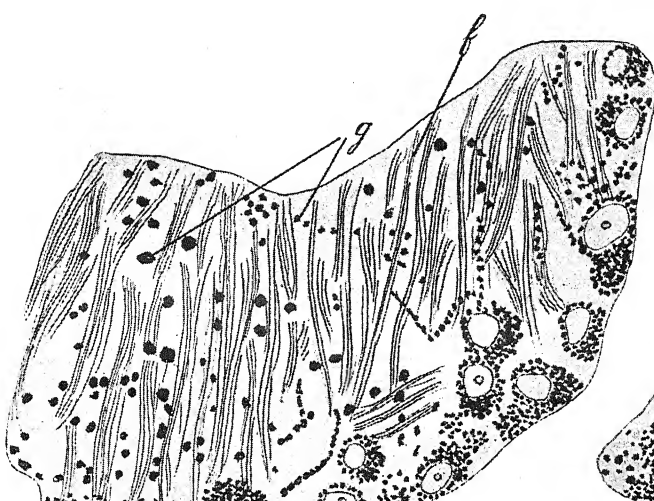


Fig 40

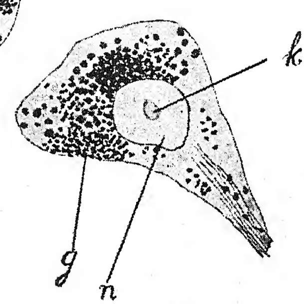


Fig 41

STUDIES IN ADSORPTION, PART XIII.

BY

MOOLRAJ MEHROTRA AND N. R. DHAR.

In a previous paper from this laboratory the adsorption of anions by freshly precipitated barium sulphate as well as during the course of its formation was determined.

Barium sulphate as ordinarily prepared is positively charged due to the preferential adsorption of Bä ions, naturally it will adsorb anions. The following order of adsorption was obtained :—

$$Cr_2O_7'' > S_2O_3'' > BrO_3' > AsO_3''' > C_2O_4'' > IO_4' > IO_3' > MnO_4' > NO_2' > Fe(CN)_6'''' > Fe(CN)_6''' > Cl' > CNS' > Br' > I'$$

We have also proved that small quantities of positive ion are also adsorbed by barium sulphate. It must be emphasised that the amount of adsorption by barium sulphate is much greater than that of a positive ion.

In this paper we have determined the adsorption of various anions and a few cations by a mixture of barium sulphate and aluminium hydroxide during the course of their formation. We have also determined the adsorption of anions by freshly precipitated aluminium hydroxide.

A solution of known strength of aluminium sulphate was prepared and a strong solution of $Ba(OH)_2$ was prepared in a carbon dioxide-free water. Equivalent quantities of two solutions were mixed with different electrolytes of a known concentration and the total volume was always made up to 100 c.c.

This reaction mixture produced $BaSO_4$ and $Al(OH)_3$ in equivalent quantities and the adsorption of anions was known by the difference in the concentrations of the original solutions of the anions and final concentrations.

When the adsorption of anions by a freshly precipitated $Al(OH)_3$ was determined equivalent amounts of standard solutions of aluminium sulphate and caustic soda were mixed in presence of different salts.

The following experimental results are obtained:—

(*a*) Adsorption of anions by a mixture of $Al(OH)_3$ and $BaSO_4$.

Amount of $BaSO_4$ = 0·7091 gram.
Amount of $Al(OH)_3$ = 0·1580 gram.
Volume = 100 c.c.; Time = 20 hours.

Adsorption of Cr_2O_7'' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·0506604	0·040098	1·0562	20·85
0·040528	0·031775	0·87528	21·59
0·030396	0·023178	0·7218	23·74
0·020264	0·013692	0·6572	32·43
0·010132	0·006063	0·4069	40·15

Adsorption of C_2O_4'' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·063126	0·057342	0·5785	9·16
0·050501	0·045396	0·5205	10·31
0·037876	0·033400	0·4426	11·68
0·025251	0·021378	0·3873	15·33
0·012625	0·009809	0·2817	22·31

Adsorption of MnO_4' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·005197	0·004757	0·04405	8·47
0·004158	0·003911	0·02867	5·93
0·003118	0·002801	0·03171	10·16
0·002080	0·001868	0·02114	10·16
0·001040	0·00081	0·00229	22·03

Adsorption of BrO_3' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·05766	0·05450	0·316	5·49
0·04613	0·04317	0·296	6·43
0·03460	0·03217	0·243	7·03
0·02306	0·02067	0·239	10·4
0·01153	0·00967	0·186	16·18

Adsorption of S_2O_3'' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·124326	0·119333	0·4193	4·01
0·0994607	0·095267	0·41936	4·61
0·074596	0·070404	0·4194	5·62
0·049730	0·044937	0·4793	9·63
0·037298	0·033450	0·3844	10·30
0·024865	0·021220	0·3645	14·65
0·012433	0·011487	0·0946	23·69

Adsorption of IO_3' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·0310	0·0268	0·42	13·44
0·0248	0·0213	0·35	13·97
0·0186	0·0155	0·31	16·66
0·0124	0·0095	0·29	23·38
0·0062	0·0040	0·22	35·48

Adsorption of NO_2' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·063412	0·062398	0·1014	1·57
0·050730	0·049318	0·1412	2·86
0·038047	0·036739	0·1308	3·43
0·025365	0·024160	0·1205	4·75
0·012682	0·010681	0·2001	15·77

Adsorption of $Fe(CN)_6''''$ ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·033229	0·031880	0·1342	4·04
0·026583	0·025342	0·1241	4·67
0·019937	0·018965	0·0972	4·88
0·013292	0·012587	0·0705	5·30
0·006646	0·006327	0·0319	4·79

Adsorption of $Fe(CN)_6'''$ ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·0590	0·0560	0·30	5·08
0·0472	0·0450	0·22	4·66
0·0354	0·0340	0·14	3·95
0·0236	0·0226	0·10	4·23
0·0118	0·0110	0·08	6·94

Adsorption of CNS' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·088028	0·087187	0·0841	0·94
0·070422	0·069749	0·0673	0·92
0·052817	0·052312	0·0505	0·92
0·035211	0·034469	0·0742	2·07
0·017606	0·017032	0·0574	3·22

Adsorption of Cl' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·128602	0·122197	0·6405	1·86
0·102882	0·100881	0·2001	1·94
0·077161	0·075160	0·2001	2·59
0·051441	0·049839	0·1602	3·11
0·025720	0·024619	0·1101	4·41

Adsorption of Br' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·128602	0·122197	0·6405	1·86

(*b*) Adsorption of anions by $Al(OH)_3$.

Amount of $Al(OH)_3 = 0·1541$ gram.

Volume = 100 c.c.; Time = 20 hours.

Adsorption of Cr_2O_7'' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·049833	0·048500	0·1333	2·67
0·039866	0·038666	0·1200	3·01
0·029900	0·028833	0·1067	3·56
0·019933	0·018833	0·1100	5·51
0·009966	0·009333	0·0633	6·35

Adsorption of C_2O_4'' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·0633131	0·058621	0·4510	7·14
0·049504	0·046596	0·2908	7·74
0·037878	0·034464	0·3414	9·01
0·025252	0·022009	0·3243	12·83
0·012626	0·0101097	0·2429	19·21

Adsorption of MnO_4' ion.

Original concentration.	Final concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·005076	0·005040	0·0036	0·78
0·004061	0·004025	0·0036	0·87
0·003046	0·003015	0·0031	0·99
0·002030	0·002000	0·0031	1·25
0·001015	0·001000	0·0015	1·50

Adsorption of BrO_3' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·05766	0·05683	0·083	1·44
0·04613	0·04533	0·080	1·73
0·03460	0·03383	0·077	2·21
0·02306	0·02250	0·056	2·44
0·01153	0·01117	0·036	3·18

Adsorption of S_2O_3'' ion.

Original concentration.	Final concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·115804	0·114441	0·1363	1·17
0·092643	0·091533	0·1090	1·17
0·069480	0·068574	0·0908	1·31
0·046322	0·045685	0·0637	1·37
0·023161	0·022661	0·0500	1·96

Adsorption of IO_3 ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·0310	0·0300	0·10	3·22
0·0248	0·0240	0·08	3·22
0·0186	0·0180	0·06	3·04
0·0124	0·0120	0·04	3·44
0·0062	0·0060	0·02	3·22

Adsorption of NO_2' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·060987	0·060987	0	0
0·048790	0·048531	0·0259	0·49
0·036592	0·035957	0·0635	1·6
0·024395	0·023971	0·0424	1·58
0·012197	0·011986	0·0211	5·54

Adsorption of $Fe(CN)_6''''$ ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·033428	0·032571	0·0857	2·56
0·026742	0·025857	0·0885	3·30
0·020057	0·019214	0·0843	4·21
0·013371	0·012714	0·0658	4·91
0·006686	0·006142	0·0544	8·11

Adsorption of $Fe(CN)_6'''$ ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·05975	0·05975	0	0
0·04780	0·04750	0·03	0·62
0·03585	0·03525	0·06	1·67
0·02390	0·02350	0·04	1·67
0·01195	0·01175	0·02	1·67

Adsorption of CNS' ion.

Original concentration.	End concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·079841	0·079562	0·0279	0·38
0·063873	0·063627	0·0246	0·38
0·047905	0·047721	0·0184	0·38
0·031936	0·031780	0·0156	0·38
0·015968	0·015873	0·0095	0·38

Adsorption of Cl' ion.

Original concentration.	Final concentration.	Adsorption in millimoles.	Percentage of adsorption.
0·125726	0·125726	0	0
0·100581	0·100336	0·0245	0·24
0·075436	0·075252	0·0184	0·24
0·050290	0·050168	0·0122	0·24
0·025145	0·025084	0·0061	0·24

Adsorption of Br' ion.

Original concentration.	Final concentration.	Adsorption in millimoles.	Precentage of adsorption.
0·126338	0·126338	0	0
0·101070	0·100642	0·0428	0·42
0·075803	0·075558	0·0245	0·32
0·050535	0·050341	0·0194	0·36
0·025268	0·025084	0·0184	0.72

From the experimental results it will be seen that the order of adsorption of different anions by a mixture of freshly precipitated $BaSO_4$ and $Al(OH)_3$ is the following:

$Cr_2O_7'' > C_2O_4'' > IO_3' > S_2O_3'' > BrO_3' > Fe(CN)_6''' >$ $MnO_4' > Fe(CN)_6'''' > Cl'$; $Br' > NO_2' > CNS'$

whilst the order of adsorption of different anions by freshly precipitated $Al(OH)_3$ is the following:

$C_2O_4'' > IO_3' > Cr_2O_7'' > Fe(CN)_6'''' > BrO_3' > S_2O_3'' >$ $NO_2' > Fe(CN_6)''' > Br', CNS' > Cl' > MnO_4'$

It will thus be seen that the adsorption of anion by the mixture of the two substances is more or less of the same order as that obtained in the adsorption of anions by barium sulphate.

PHENOMENON OF AFTER-EFFECT IN CERTAIN PHOTOCHEMICAL REACTIONS.

BY

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In previous papers (Dhar Z. Anorg. Chem., 1922, *121*, 1561; Jour. Chem. Soc., 1923, 123, 1856) it has been mentioned that the reaction between potassium oxalate and iodine is very sensitive to light. We have observed that a mixture of potassium oxalate and iodine when exposed to light and brought back to darkness shows a greater velocity in the dark than when the reacting mixture is not at all exposed to light. This phenomenon is known as "After-effect" in photochemical reactions.

The phenomenon of "After-effect" has already been noted in certain photochemical changes. In solvents other than alcohol the "Oxidation" of iodoform as studied by Plotnikow (Z. Physik. Chem., 1911, *76*, 743) shows a marked after-effect when illumination has ceased. Trautz and Thomas (Physik. Z. 1906, *7*, 899; Z. Elektrochem, 1907, *13*, 550; Z. Wiss. Phot., 1906, *4*, 352) note after-effect of illumination in the photo-oxidation of sodium sulphide, of cuprous chloride in hydrochloric acid solution and of benzaldehyde. That the benzaldehyde oxidation shows an after-effect when illumination is discontinued has been confirmed by Bäckström (Taylor's Physical Chemistry, page 1247). Kistiakowski (Z. Physik. Chem., 1900, *35*, 431) observed an after-effect of illumination in the case of the photo-decomposition of hydrogen peroxide by visible light in presence of ferro- and ferri-cyanides.

With a view to test whether any after-effect of illumination takes place or not in photo-sensitive reactions we investigated a number of reactions in aqueous solutions. Some of these reactions are known to be markedly photo-sensitive either to visible or to ultra-violet light while others are only moderately so.

The experiments were carried out as follows:—A 500-c. p. point-o-lite lamp was used as the source of illumination. The reactions took place in a beaker which was placed at a measured distance apart from the light source. The light was switched on as soon as the reactants were mixed together and after a few minutes of exposure it was turned off. The beaker was immediately removed to complete darkness, 5 c.c. of the mixture withdrawn and the amount of change in it determined by titration. Further readings were continued to be taken by thus placing the reacting system in darkness. The reacting mixtures were again mixed together in a beaker identically as before, but this time instead of exposing the system to the point-o-lite lamp for the first few minutes it was kept all along in the dark and readings taken at intervals.

The following experimental results were obtained :—

Table I. *Potassium oxalate and Iodine.* Temperature 32°C.
N/10—Potassium oxalate and N/137—Iodine.
Distance from the point-o-lite lamp = 21 cms.

Exposed to light for 5 minutes and then removed to darkness.			In the dark throughout.		
t (minutes)	a-x (c.c.)	k_1 (unimolecular)	t (minutes)	a-x (c.c.)	k_1 (unimolecular)
0	7·3	...	0	7·3	...
5	6·5	·0101	$7\frac{1}{2}$	6·7	·00496
15	5·75	·00691	20	5·9	·00462
30	4·65	·00653	40	4·65	·00489

Table II. *Tartaric acid and Bromine.* Temp. 32°C.
N/10—Tartaric acid and N/111·2—Bromine.
Distance from the point-o-lite lamp=21 cms.

Exposed to light for 5 minutes and then removed to darkness.			In the dark throughout.		
t (minutes)	a-x (c.c.)	k_1 (unimolecular)	t (minutes)	a-x (c.c.)	k_1 (unimolecular)
0	9·0	...	0	9·0	...
5	3·9	·0726	5	7·8	·0124
12	2·5	·0464	12	6·7	·0107
20	1·0	·0477	20	4·1	·0171

Table III. *Lactic acid and Bromine.* Temp. 32°C.
N/10—Lactic acid and N/125—Bromine.
Distance from the point-o-lite lamp=21 cms.

Exposed to light for 5 minutes and then removed to darkness.			In the dark throughout.		
t	a-x	k_1	t	a-x	k_1
0	8·0	...	0	8·0	...
5	4·35	·0529	6	6·4	·0162
12	2·7	·0393	15	4·1	·0194
20	1·5	·0364	30	1·8	·0216

Table IV. *Malic acid and Bromine.* Temp. 32°C.
N/10—Malic acid and N/125—Bromine.
Distance from the point-o-lite lamp = 21 cms.

Exposed to light for 5 minutes and then removed to darkness.			In the dark throughout.		
t	a-x	k_1	t	a-x	k_1
0	8·0	...	0	8·0	...
5	3·35	·0756	5	6·0	·0249
12	2·3	·0451	12	4·5	·0209
18	1·4	·0421	25	2·2	·0224

Table V. *Oxalic acid and Bromine.* Temp. 32°C.
N/10—Oxalic acid and N/111·2—Bromine.
Distance from the point-o-lite lamp=27 cms.

Exposed to light for 5 minutes and then removed to darkness.			In the dark throughout.		
t	a-x	k_1	t	a-x	k_1
0	9·0	...	0	9·0	...
5	1·9	·1351	6	3·3	·0726
12	0·75	·0899	12	1·3	·0702
20	0·2	·0828	20	0·45	·0651

Table VI. *Citric acid and Bromine.* Temp. 32°C.
N/10—Citric acid and N/136—Bromine.
Distance from the point-o-lite lamp = 21 cms.

Exposed to light for 5 minutes and then removed to darkness.			In the dark throughout.		
t	a-x	k_1	t	a-x	k_1
0	8·4	...	0	8·4	...
5	6·25	·0257	$9\frac{1}{2}$	5·8	·0171
15	4·2	·0202	20	3·75	·0175
30	2·3	·0188	35	2·0	·0170

Table VII. *Potassium formate and Iodine.* Temp. 32°C.
N/6.4—Potassium formate and N/100—Iodine.
Distance from the point-o-lite lamp=21 cms.

Exposed to light for 5 minutes and then removed to darkness.			In the dark throughout.		
t	a-x	k_1	t	a-x	k_1
0	10·0	...	0	10·0	...
5	7·0	·0309	5	7·9	·0205
12	5·6	·0209	12	5·8	·0200
20	3·6	·0222	20	3·9	·0205

Table VIII. *Sodium citrate and Iodine.* Temp. 32°C.

N/11·6—Sodium citrate and N/137—Iodine.

Distance from the point-o-lite lamp = 21 cms.

Exposed to the light for 5 minutes and then removed to darkness.			In the dark throughout.		
t.	a-x.	k_1.	t.	a-x.	k_1.
0	7·3	...	0	7·3	.
5	5·8	·0200	8	6·3	·00800
15	5·1	·0104	25	5·1	·00623
30	4·4	·00733	45	3·7	·00655
		Mean = ·00886			Mean = ·00693

Table IX. *Oxalic acid, Chromic acid, Manganous sulphate and Sulphuric acid.* Temp. 32°C.

N/30—Oxalic acid, N/517·2—Chromic acid, N/11·4—Sulphuric acid and N/600—Manganous sulphate.

Distance from the point-o-lite lamp=21 cms.

Exposed to light for 3 minutes and then removed to darkness.			In the dark throughout.		
t.	a-x.	$k_0 = \frac{x}{t}$	t.	a-x.	$k_0 = \frac{x}{t}$
0	9·3	...	0	9·3	...
3	7·8	·50	$3\frac{1}{2}$	8·05	·36
8	6·05	·41	8	6·5	·35
$12\frac{3}{4}$	3·3	·47	13	4·7	·35

Table X. *Oxalic acid, Potassium permanganate, Manganous sulphate and Sulphuric acid.* Temp. 23°C.

N/30—Oxalic acid, N/5064—Potassium permanganate, N/600—Manganous sulphate and N/11·4—Sulphuric acid.

Distance from the point-o-lite lamp=21 cms.

Exposed to light for 45 seconds and then removed to darkness.			In the dark throughout.		
t.	a-x.	k_1	t.	a-x.	k_1
0	7·95	...	0	7·95	...
$\frac{3}{4}$	5·5	·210	$1\frac{1}{2}$	4·1	·192
$1\frac{1}{2}$	4·2	·185	3	2·35	·176
3	3·2	180	4	2·1	·145
		Mean=·183			Mean=·171

Table XI. *Potassium persulphate and Potassium Iodide.* Temp. 32°C.

N/12—Potassium Iodide and N/100—Potassium persulphate exposed to moderately bright sunlight.

Exposed to sunlight for 1 minute and then removed to darkness.			In the dark throughout.		
t.	a-x.	$k_0=\frac{x}{t}$	t.	a-x.	$k_0=\frac{x}{t}$
0	0	...	0	0	...
1	2·4	2·4	$1\frac{1}{2}$	2·5	1·667
$3\frac{1}{4}$	6·2	1·907	$4\frac{1}{4}$	7·2	1·694
5	9·4	1·880	6	10·2	1·700

It is well known that the reaction between ferric chloride and ammonium oxalate is very sensitive to sunlight, so this reaction, too, was studied to test if there existed any after-effect of illumination. Some ferric chloride, a larger quantity of ammonium oxalate and a few crystals of oxalic acid were

mixed together and divided into two portions. One portion was exposed to bright sunlight while the other was kept in total darkness. The portion exposed to the sun began to show a precipitate of ferrous oxalate in about 10 minutes. As soon as the precipitate began to come out the solution was removed to a dark room and filtered through double-filter paper. The clean filtrate was now kept in total darkness and in about half-an-hour quite a large amount of precipitate was noted in this filtrate. The other portion of the original mixture which had been kept in the dark showed no formation of precipitate even after a much longer period.

It is evident that all the reactions investigated above are accelerated to a certain extent by the light from a point-o-lite lamp and it is to be observed that all these light-sensitive reactions when once exposed to the light for the first few moments proceed (in the absence of the light) with an appreciably greater velocity than in the case when the reactions take place all along in the dark.

The following figures will show the amount of acceleration caused by the light as well as the corresponding increase in the velocity of the reactions after the point-o-lite lamp has ceased to work over the velocity of the reactions proceeding all along in the dark :—

Table XII.

Reaction.	Acceleration in the velocity produced by light.	Velocity of the dark reaction after the light has ceased to work. / Velocity of the reaction in the dark all along.
Tartaric acid and Bromine (Table II)	5·4 times	$\frac{\cdot 047}{\cdot 013} = 3\cdot 7$
Lactic acid and Bromine (Table III) ...	3·2 ,,	$\frac{\cdot 038}{\cdot 019} = 2\cdot 0$

Reaction.	Acceleration in the velocity produced by light.	Velocity of the dark reaction after the light has ceased to work. / Velocity of the reaction in the dark all along.
Malic acid and Bromine (Table IV) ...	3·2 times	$\frac{\cdot044}{\cdot023}=1\cdot95$
Sodium citrate and Iodine (Table VIII) ...	2·9 ,,	$\frac{\cdot0089}{\cdot0069}=1\cdot3$
Potassium oxalate and Iodine (Table I) ...	2·1 ,,	$\frac{\cdot0067}{\cdot0048}=1\cdot4$
Oxalic acid and Bromine (Table V)	1·9 ,,	$\frac{\cdot087}{\cdot070}=1\cdot2$
Citric acid and Bromine (Table VI)... ...	1·5 ,,	$\frac{\cdot019}{\cdot017}=1\cdot1$
Potassium formate and Iodine (Table VII) ...	1·5 ,,	$\frac{\cdot022}{\cdot020}=1\cdot1$
Oxalic acid, Chromic acid, Manganous sulphate and Sulphuric acid (Table IX)	1·43 ,,	$\frac{\cdot44}{\cdot35}=1\cdot23$
Postassium persulphate and Potassium iodide (Table XI) ...	1·42 ,,	$\frac{1\cdot90}{1\cdot69}=1\cdot13$
Oxalic acid, Potassium permanganate, Manganous sulphate, and Sulphuric acid (Table X) ...	1·2 ,,	$\frac{\cdot183}{\cdot171}=1\cdot07$

From the above table it is at once evident that there exists a proportionality between the ratio of the velocity of a reaction in the dark after the light has ceased to work to the velocity of the reaction throughout in the dark and the corresponding acceleration of the velocity of the reaction by the light. In other words, the greater the acceleration caused by the light, the greater is the after-effect produced in the reaction.

Among the reactions investigated by us we observed a few cases which in spite of being markedly photo-sensitive exhibit no after-effect. The reaction between sodium-potassium tartrate and bromine is accelerated by light, yet the ratio

of the velocity of the reaction in the dark after the light has ceased to work to the velocity in the dark all along remains almost unity. A mixture of mercuric chloride and ammonium oxalate was exposed to sunlight and just when some calomel began to form, it was filtered off and the filtrate kept in a dark room. No further precipitation of calomel took place in the filtrate in the dark. Again, the decompositions of Fehling's solution and a mixture of an oxalate and copper sulphate solution take place readily in strong sunlight and deposit of copper is obtained; but in none of these cases any after-effect was observed after illumination.

It is very difficult to explain the after-effect in photochemical reactions and no satisfactory suggestion in explaining this phenomenon has yet been advanced.

We shall cite certain facts which are more or less allied to these photochemical after-effects. Phillips (Proc. Roy. Soc., 89, 42, 1913) exposed mercury-vapour in a quartz tube to radiations containing $\lambda = 2537$A° from a mercury lamp. He found that the mercury-vapour began to fluoresce and he observed that the glow passed up the tube and spread out to a distance of 18 inches from the place of illumination.

In a previous paper (Zeit. Anorg. Chem., *141*, 1, 1924) we have suggested an explanation of this observation of Phillips in the following way:—

The atoms of mercury in the mercury-vapour become activated by the absorption of light $\lambda = 2537$A°. The activated atoms in losing the extra amount of energy can give out radiation and can emit the glow. Now, the activated atom in coming in contact with an inactive atom which has not been illuminated can impart its energy to the inactive atom and activate it. This process can repeat itself and a long column of mercury-vapour becomes activated and gives a glow though not illuminated. Though the life period of an activated atom or molecule is of the order 10^{-8} sec. it seems probable that by these collisions the glow can continue to a much longer period.

It was observed originally by Stark (Ann. Phys., *14*, 520, 1904) that a stream of mercury-vapour allowed to distil away from the arc or glow discharge in vacuo remains luminous. It may be said to carry the luminosity away with it and in the case of the arc discharge there is no difficulty in detecting the luminosity for 50 cm. or so from the source.

Lord Rayleigh has obtained more or less similar results (Proc. Roy. Soc., A Vol., *90*, 364, 1914; *91*, 92, 1914; *108*, 262, 1925). Consequently, there is absolutely no doubt in the fact that light persists in the vapour even after the source of excitation has been removed and this is exactly a phenomenon of the same nature as the after-effect in photochemical reactions and we are of opinion that the causes of both the phenomena would be identical. It seems possible in photochemical reactions that on illumination some of the molecules of the reacting substances become activated and these activated molecules by impact can activate other inactive molecules and this process is likely to take time and consequently, when the source of illumination is removed, the activated molecules take some time to die out and hence the chemical action persists for a short time even after the illumination is cut off.

Franck and Grotrian (Zeit für Physik, *4*, 89, 1921) have repeated the experiment of Phillips and have accounted for the persistence of the luminosity by supposing that the excited atoms which have absorbed $\lambda = 2537 A^{\circ}$ and are prepared to re-emit this line unite with other mercury atoms to form molecules. When these molecules are again dissociated, the stored energy can be liberated and $\lambda = 2537 A^{\circ}$ is emitted.

Several years ago Weigert (Ann. Physik, *24*, 243, 1907) threw out the suggestion that a photochemical change may consist in the intramolecular transformation of the molecules of the light-absorbing substance or in the formation of molecular complexes which act as reaction nuclei under illumination. It is needless to say that there is hardly any experimental

support to these conjectures. Similarly, for lack of experimental support this phenomenon of after-effect cannot be associated with the existence of chain reactions or intermediate-compound formations. That a series of frequencies is active in a chemical change is explained by Perrin (Ann. Physique, 1919, *11*, 1; Trans. Farady Soc., 1922, *17*, 547) and by Lewis (Jour. Chem. Soc., 1922, *121*, 613) by assuming that such reactions take place in steps with the formation of intermediate compounds. Though it may be true in a few cases, yet in the majority of reactions the validity of this assumption cannot be experimentally proved. The very recent developments of the "activation theory" seem to do away with the necessity of such arguments.

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STUDIES ON THE OXIDES OF NICKEL.

BY

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It appears from the researches of Belluci and Clavari (Atti. R. Acad. Lincie, 1905, *14 ii*, 234) that the compound Ni_2O_3 is not obtained when oxidising agents are added to a nickel salt and alkali. They assert that the compound NiO_2 is obtained.

In order to ascertain the composition of this oxide and to know whether it remains constant even after heating, Kahlbaum's black nickel oxide was taken. This was heated on the Bunsen flame when it lost 5·4% of its weight, and the colour changed into bluish black. It was further very strongly heated on the blowpipe, when although the colour very slowly changed to dirty green, which acquired bluish shade on cooling, no loss in weight was observed. The mass was nitrated and strongly heated again. No change in weight was observed. The ignited mass, like many ignited oxides, is slightly hygroscopic in nature.

In order to get direct information on the point, it became necessary to prepare the pure black oxide. The usual salts of nickel could not be tried as iron was found in many of them. For a standard solution of nickel, pure Kahlbaum's nickel was taken. It was dissolved in the least quantity of nitric acid and the solution was diluted to a known volume. For checking, the solution was analysed by a number of methods, as for example,

(1) Precipitation as glyoxime, in the Gooch crucible. This gave quite a good value.

(2) Precipitation as glyoxime and ignition. Taking the ignited product as NiO, a low value was obtained, due apparently to the partial reduction of NiO.

(3) Precipitation as $Ni(OH)_2$ by pure NaOH and ignition. Impure NaOH containing Na_2CO_3 gives a product which turns black on ignition.

(4) Precipitation as nickelic oxide by Bromine and NaOH, and ignition.

Both (3) and (4) gave good values. In (3) after ignition, a green mass, the usual NiO, was obtained, but in (4) although the mass corresponded to the weight of NiO, it was black in colour.

(5) Evaporation of the solution and strong heating of the residue. This, also, gave a good value.

It may be noted here that all the ignitions were carried on in platinum crucibles and that in every case, a check was effected by reducing the residue with hydrogen and weighing out the reduced nickel.

The following points were observed—

(1) Nickelic oxide decomposes easily into practically nickelous oxide, in platinum vessels, on the Bunsen flame.

(2) The so-prepared nickelous oxide comes out black, and becomes green, only on strong heating with the blowpipe.

(3) In every case, the so-prepared nickelous oxide is found to be slightly above the theoretical weight.

The average factor was found to be 1·005. No comment is being made at the present stage, as to the cause of this. That it was not due to adsorbed alkali, was clear from the fact that this result was obtained even in those cases where the nickel was tested and was found free from alkali. Moreover the same result was obtained in the

method (5), namely, the evaporation and ignition method of obtaining nickelous oxide from nickel nitrate solution.

As preliminary experiments, a sample of the black nickel oxide was carefully prepared from the standard nickel solution by NaOH and bromine and was dried in air. It was then placed in an air oven and kept at a temperature of 130°C. A loss in weight of 25·3% was observed, but the figure began gradually to increase and eventually came to 31·2% in about a week's heating of 4 hours a day. A further loss of ·3% took place on igniting the residue on the blowpipe, thus making the total loss equal to 31·5%.

The calculated loss in weight of $Ni_2O_3,3H_2O$ as it passes to Ni_2O_3 and to NiO are respectively 24·6% and 31·9%.

Two samples of the black oxide were precipitated in Gooch crucibles and were kept in the air oven for drying. The masses obtained, when some constancy in weight were observed, corresponded to the formulæ $Ni_2O_3, 2H_2O$ and Ni_2O_3, H_2O. It was also found that the NiO, obtained from the dihydrate, was equal to 75%.

Calc. NiO from $Ni_2O_3, 2H_2O = 74·4\%$.

It was also found that these hydrated oxides gained in weight if they were kept over water and thus seemed to pass to higher stages of hydration.

Other samples, similarly prepared and kept in the air oven gave similar results, namely, loss of water molecules is brought about by progressive heating, in the hydrated black oxide of nickel.

It is thus seen that determination of water and of NiO in the black oxide point to the formula $Ni_2O_3, 3H_2O$.

Attempts were made to estimate the "oxidising" oxygen in this oxide, with the following results—

(1) KI and H_2SO_4 were added to the stuff and the liberated iodine was titrated. Very low values were obtained.

(2) Oxalic acid and sulphuric acid were added. The mixtures in some cases were kept cold, and in others heated, and then the excess of oxalic acid was determined in the usual manner by $KMnO_4$. Values, still quite low, were obtained.

(3) A preliminary experiment was made of the effect of nitric acid on oxalic acid, and as it was found that under carefully regulated conditions, practically no action took place, the precipitated black oxide was added to such mixtures, and, after the reaction was over, the excess of oxalic acid was determined in the usual way. Better values were obtained, but still they were not quite concordant.

Incidentally, we may say here, that certain other methods will be tried later on.

A better estimation of the amount of water was next made, by the " combustion " process, namely, by heating the stuff in a porcelain boat in a hard glass tube. To one end of it a weighed Geissler bulb containing H_2SO_4 was attached, which was connected to another sulphuric acid bulb preceded by a U-tube containing $CaCl_2$ and soda lime. This was connected to a hand blower, by squeezing which, air could be forced in through the apparatus. The other end of the combustion tube was drawn out and was attached to two successive Geissler bulbs. These contained sulphuric acid and were weighed. To the last was attached another sulphuric acid bulb to act as guard. It will be noticed that the combustion tube had one weighed bulb at the end through which air entered and another weighed bulb on the other side just before the 'guard.' These bulbs retaining their weights showed conclusively that the air that entered was dry, that there happened no back rush of the water-vapour produced on ignition and that this water-vapour could be completely absorbed in the first absorbing bulb. Sulphuric

acid was found to be a more suitable absorber than calcium chloride and the hand blower was found to be a far better arrangement to put in dry air and to force its passage through the bulbs. It will also be noticed that the other end of the bulb was drawn out to the diameter of the connecting tube of the Geissler bulb, to which, mouth to mouth, it was attached. The arrangements proved excellent and gave accurate results. This apparatus was utilized in the direct determination of water in the precipitated black nickel oxide. The residue in the boat was then separately reduced in hydrogen and the amount of nickel determined. The percentages of nickel and water gave indirectly the percentage of oxygen. Thus, the composition of the various products, mentioned later on, could be determined. Some of the analyses are given below:

(1) Kahlbaum's black nickel oxide. Many analyses were made of which the following is one taken at random:

Found $H_2O = 4{\cdot}7\%$ and $Ni = 74{\cdot}02\%$.

Calculated for $14NiO$, Ni_2O_3, $3H_2O$,— $H_2O = 4{\cdot}3\%$ and $Ni = 74{\cdot}2\%$.

The "oxidising" oxygen was also directly determined by the oxalic acid plus nitric acid method.

Found oxygen$=1{\cdot}3\%$.

Calculated for $14NiO$, Ni_2O_3, $3H_2O$, oxygen$=$ $1{\cdot}2\%$.

It will be observed that the residue that was obtained, by strong heating, of the stuff was $94{\cdot}6\%$, whereas NiO computed from the formula is $94{\cdot}3\%$. It supports the view that the weight of nickelous oxide obtained by strongly heating the black oxide comes out somewhat higher than what it ought to be.

(2) Hydrated black oxide, precipitated by pure NaOH and Bromine, adding these not more than just

a little excess. The following is the result of one of the numerous analyses made:

Found $Ni = 53{\cdot}5\%$ and $H_2O = 24{\cdot}7\%$.
Calculated for Ni_2O_3, $3H_2O$, $Ni = 53{\cdot}5\%$ and $H_2O = 24{\cdot}6\%$.

Hence it may be concluded, that with bromine and NaOH, adding them just in excess, the compound Ni_2O_3, $3H_2O$ is precipitated.

The next point was to determine what could be precipitated if bromine be added carefully avoiding any excess of it. Several samples were prepared and analysed. Two of them gave the formula Ni_3O_4 with different amounts of hydration but the rest were of the composition Ni_2O_3, $3H_2O$. The evident conclusion is that if bromine be in deficiency, mixtures of Ni_2O_3 and NiO are formed. These mixtures, probably of their black color, are wrongly sometimes taken as Ni_2O_3.

The effect of various other oxidising agents were tried:

(1) Potassium persulphate and NaOH gave a dense black precipitate which, on analysis, proved to be the usual Ni_2O_3, $3H_2O$.

(2) If oxygen be passed in nickelous hydroxide in presence of a little sodium sulphite, the green hydroxide gets gradually converted into the black hydrated oxide. (*Vide* Dhar: Induced Oxidation.) Sufficient oxygen was passed in order to allow as much of the nickelous hydroxide to get converted into the black variety as could possibly do, under the circumstances mentioned above; several samples were thus prepared.

Analyses showed them to be mixtures, as they presented formulæ like Ni_6O_7, $9H_2O$. It was

also observed that if these hydroxides be kept for sometime, they gradually pass into the green variety. It shows that the mixtures are unstable and pass gradually on exposure into nickelous oxide.

(3) H_2O_2 in presence of alkali gives $Ni(OH)_2$, the hydrogen peroxide breaking up.

(4) Iodine and NaOH give out mixtures, containing only small quantities of the higher oxide. The mixtures are unstable and rapidly break up into $Ni(OH)_2$ on washing with hot water.

It seems, therefore, that the oxide that gets precipitated with alkali and such oxidising agents as above, is Ni_2O_3, $3H_2O$, but that this is often accompanied with nickelous oxide, if there be deficiency of the oxidising agent.

Incidentally we wanted to investigate what amount of nickel oxide would get precipitated, along with ferric oxide, if a mixture of iron and nickel salts be precipitated in the usual way in presence of ammonium salts. Preliminary experiments showed that adsorption of nickel decreases with increase of dilution and of the added ammonium salt.

The following is the result of one of the series of experiments conducted for this purpose :

Standard solutions of pure ferrous ammonium sulphate and pure nickel nitrate were prepared, and as check their values were determined.

8 c.c. ferrous ammonium sulphate solution was equivalent to ·1320 gm. of Fe_2O_3 and 8 c.c. nickel nitrate solution was equivalent to ·1160 gm. NiO. While precipitating, oxidation of the ferrous salt solution was brought about by hydrogen peroxide. This was of advantage as all operations could be done in cold. In oxidising with nitric acid, the mixture has to be warmed, which means evaporation and also decomposition of the acid as it gets

reduced, and so neither the total volume remains constant nor the amount of ammonium nitrate, that gets generated by the ammonia later on, can be foretold. Hence, these disadvantages being absent, more control is possible with H_2O_2.

Mixture taken.	H_2O_2 added.	H_2O now added.	Total ammonium salts present, put in terms of NH_3 (not NH_4Cl).	NH_4OH added.	Total resulting volume.	Precipitate washed with hot water (in litres).	Amount of Fe_2O_3 got (theoretical amount = ·1320).
(1) 8 c.c of each solution	1·5c.c	0 c.c.	·5 gm.	4 c.c.	21·5 c c.	1 litre	·1760 gm.
(2) Do.	do.	250 c.c.	do.	do.	271·5 c.c.	do.	·1942 gm.
(3) Do.	do.	500 c.c.	do.	do.	521·5 c.c.	do.	·2196 gm.
(4) Do.	do.	0 c.c.	Saturated with NH_4Cl.	do.	21·5 c.c.	do.	·1462 gm.
(5) Do.	do.	250 c.c.	2·5 gm.	do.	271·5 c.c.	do.	·1578 gm.
(6) Do.	do.	500 c.c.	5·0 gm.	do.	521·5 c.c.	do.	·1500 gm.
(7) Do.	do.	0 c.c.	Saturated with NH_4Cl.	do.	21·5 c.c.—the precipitate is then dissolved and reprecipitated in 21·5 c.c. and washed with 1 litre—Fe_2O_3 = ·1344 gm.		
(8) Do.	do.	0 c.c.	13 gm. NH_4Cl.	do.	21·5 c.c.—then reprecipitated and washed with 1 litre—Fe_2O_3 = ·1394 gm.		

It is clear that the adsorption decreases with dilution. Hence to precipitate iron in presence of nickel, it is necessary to have a dilute solution to start with, saturated with NH_4Cl. It is also advisable to dissolve the precipitate and reprecipitate it under the above conditions.

SOME OBSERVATIONS ON THE PHENOMENON OF COAGULATION AND ADSORPTION.

BY

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It is well known that during the process of coagulation a portion of the electrolyte instrumental in producing the change is taken down by the coagulum. Crum[1] as early as 1854 found that in the coagulation of suspended aluminium hydroxide, the coagulum always entrained small quantities of the acid or salt added for coagulation. Linder and Picton[2] found, in the case of the coagulation of arsenious sulphide sol by the addition of $BaCl_2$, that the coagulum carried down a distinct amount of barium ions and the filtrate becomes acidic. The adsorption of barium ions in the precipitated arsenious sulphide can be demonstrated by displacing the entrained barium ions by shaking the coagulum with a concentrated solution of KCl, NH_4Cl, etc. This specific adsorption of a precipitating ion by a colloid during the process of its coagulation was extended by Whitney and Ober,[3] who showed that the amounts of metals Ca, Ba, Sr and K taken down by the coagulum from the same amount of a given colloid (arsenious sulphide) were exactly proportional to the equivalent weights of these metals. They have indicated that this adsorption can be represented by the formula:—

$$Ba.\ 90\ (As_2\ S_3).$$

[1] Ann. Chem. Pharm., *89*, 156 (1854).

[2] Jour. Chem. Soc., *67*, 64 (1895).

[3] Jour. Amer. Chem. Soc., *23*, 842 (1901).

This simple relation is in itself a very suggestive one, but the later experiments of Freundlich and Schuct,[1] Ishizaka,[2] Weiser and collaborators[3] and others show that this simple rule cannot hold in most of the cases studied so far.

In a previous paper[4] we have shown that the phenomenon of adsorption observed during the process of coagulation is a complicated one and the simple rule need not be followed. The adsorption of ions carrying an opposite charge should naturally be equivalent, if the phenomenon of adsorption stops with the charge neutralisation and subsequent coagulation. We have indicated that the neutralised particles can take up selectively either ion of the added electrolyte, so that the amount of adsorption studied is certainly specific and is not equivalent for different coagulating ions. Moreover, the phenomenon of coagulation is still obscure.

Freundlich has shown that the amount of an ion carried down by the coagulum is given by the familiar equation $x = aC^{\frac{1}{n}}$, where x = amount adsorbed by a given amount of the adsorbent, C = concentration of the adsorbed substance and a and n are constants. Freundlich considers that a and n do not vary with the nature of the electrolyte, irrespective of the valency of the ion; consequently, if electrochemically equivalent quantities must be adsorbed in order to produce coagulation, the concentration of ions of different valencies necessary to produce coagulation differ in accordance with the Schulze-Hardy law. Freundlich has found some agreement with his theoretical result in the case of light metals, whilst the salts of heavy metals and complex organic radicals seem to be adsorbed in abnormally large quantities. Freundlich's view has been recently criticised by Ostwald[5] who has shown that both a and

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[1] Zeit. Phys. Chem., *85*, 641 (1913).

[2] Zeit. Phys. Chem., *83*, 97 (1913).

[3] Jour. Phys. Chem., *24*, 30, 630 (1921) ; *25*, 399 (1921).

[4] Dhar, Sen and Ghosh, Jour. Phys. Chem., *28*, 457 (1924).

[5] Koll. Zeit., *26*, 28, 69 (1920).

n vary for different electrolytes, which tend to invalidate Freundlich's fundamental assumption.

It is now customary to believe that the greater the amount of adsorption of an ion the greater is its coagulating power and consequently it follows from the Schulze-Hardy law (which postulates that the greater the valency of an ion the greater is its coagulating power) that the greater the valency of an ion the greater is its amount of adsorption. We [1] have, however, shown that there exists no justification in holding this view and most of the experimental results prove that the greater the valency (and therefore its coagulating power) the less is its amount of adsorption, because considering the phenomenon of coagulation by an electrolyte a process of adsorption for charge neutralisation, it is more than evident that the greater quantities of an univalent ion are necessary to coagulate a sol than a bivalent ion, which is required in greater quantities than a trivalent ion to bring about charge neutralisation of a given amount of a colloidal solution.

I am, however, inclined to consider that the phenomenon of coagulation depends upon the following four factors :—

1. The valency of the oppositely charged ion.
2. The adsorbability of the oppositely charged ion.
3. The adsorbability of the ion bearing the same charge as the colloidal particles, and
4. The rate of diffusion or the ionic velocity of the coagulating ion.

Let us consider the effect of an added electrolyte say $BaCl_2$ to a colloidal solution of arsenious sulphide. The colloidal particles are negatively charged due to the preferential adsorption of S' or HS' ions from the weak acid H_2S and the counterpart $H^{\cdot}$ ions form a second sheet of the Helmholtz double layer. This can be represented thus

$$[(As_2S_3)_n\ (HS')_y.\ KH_2O]YH^{\cdot}$$

[1] Compare Dhar, Sen and Ghosh, loc. cit.

On the addition of the electrolyte the cations are attracted and adsorbed by the negatively charged colloid particles, whence charge neutralisation and coagulation occurs. The barium ions entrained in the coagulum and the acid is set free as is shown in the equation $[(As_2S_3)_n\ (HS)_y.\ KH_2O]YH^{\cdot} + \frac{y}{2}\ BaCl_2 = [(As_2S_3)_n(HS)_y.\ KH_2O\frac{y}{2}Ba] + YHCl$.

It is evident that provided there is no further complication, amounts proportional to the equivalent weights of different coagulating ions are taken down by the coagulum. But as a matter of fact, we[1] have shown that enough of chloride ions are adsorbed by As_2S_3, which will require greater quantities of $Ba^{\cdot\cdot}$ ions to produce charge neutralisation. With some electrolytes (like salts of alkaloids, heavy metals, etc.), the As_2S_3 possesses an extra attraction for adsorption besides that due to its electric charge, and the cations are further adsorbed after charge neutralisation and coagulation.

One remarkable fact observed with the phenomenon of coagulation on the addition of an electrolyte is that a minimum quantity of the electrolyte must be added to produce agglomeration of colloid particles in a definite time. Our researches on the adsorption and coagulation of As_2S_3, Sb_2S_3 sols show that the actual amount of cations taken down by the precipitate from such electrolytes as KCl, $BaCl_2$, etc., is only 2% of the added electrolyte, whilst the rest is left unaffected. It will be interesting here to observe that in spite of the fact, that there exists an electric charge on colloid particles, the oppositely charged cations do not produce any perceptible change in a given time if the concentration of the coagulant is below the minimal concentration or 'threshold value.'[2]

Burton has determined the effect of $Al_2(SO_4)_3$ when added to a silver sol by measuring the velocity of the colloid particles in an electric field. The colloid, which by itself is

[1] Compare Ghosh and Dhar, Koll. Zeit., *36*, 129 (1925); Jour. Phys. Chem., *29*, 435 (1925).

[2] Also compare Galeki, Zeit. Anorg. Chem., *74*, 174 (1912).

negatively charged, becomes eventually positively charged on the continued addition of $Al_2(SO_4)_3$. He found that the movement of the colloid particles will be zero and, therefore, the isoelectric point is reached at the region, in which the concentration of $Al^{\cdots}$ ions is 26×10^{-6} grams per 100 c.c. Burton[1] in calculating the charge on the colloid particles assumes that the whole of the charged $Al^{\cdots}$ ions took part and found that each colloid particles carry a charge of $2{\cdot}8 \times 10^{-2}$ electrostatic units. If we assume Burton's[2] value for 'e' correct and calculate the potential difference between the particles and the medium it is 33 volts, which is of course quite impossible. The potential difference for a colloid particle calculated from the expression of Lamb[3] is 0·056 volt, which shows that only $\frac{1}{600}$ portion of the critical concentration of $Al^{\cdots}$ ions is effective for charge neutralisation and subsequent coagulation. No satisfactory explanation has yet been given of these facts.

It has been assumed from the works of Helmholtz and Lamb that an electrically charged particle, say As_2S_3 is surrounded by a layer of ions of opposite charge. I have indicated that the colloid particle is charged negatively and there exists a sheet of oppositely charged $H^{\cdot}$ ions, so that the effect of the system as a whole is greatly minimised. If the charges on the colloid particles and in the double layer were fixed, it is evident that there would have been no effective charge. In connection of cataphoresis, we must, therefore, assume that the movement in an electric field is only made possible by the fact that there exists a certain 'slip' or 'give' between the two coatings of the double layer. Now, when an electrolyte, say KCl is added to the sol, the positively charged potassium ions are not instantly attracted by the oppositely charged As_2S_3 particles, for as soon as the cations approach sufficiently

[1] Physical Properties of Colloidal Solution by Burton, page 165 (1921).

[2] Also compare Lewis, Koll. Zeit., *4*, 209 (1909).

[3] Phil. Mag., page 60 (1888).

near the double layer of $H^{\cdot}$ ions they do not find a seat and cannot effectively meet the colloidal suspension ; consequently when KCl is added in a very small quantity the cations are helpless in bringing about coagulation, for they cannot penetrate the sheet of $H^{\cdot}$ ions and meet the colloidal particles to neutralise the charge and produce precipitation. On increasing the concentration of KCl, however, the diffusion of $K^{\cdot}$ ions markedly increases and when a limiting value is reached, it can penetrate the double layer and meet the central colloid particle and, therefore, produces a partial neutralisation of the electric charge and subsequent coagulation. If, the concentration of KCl is further increased, the diffusion of the cations also increases and the coagulation is rapid. In the case of bivalent and trivalent coagulating ions the electric attraction by the colloid particles is far greater than that on the univalent cations, simply because the net amount of electric charge is greater in the former cations than latter ones; consequently smaller quantities of bivalent and trivalent cations can easily coagulate a given amount of a colloidal solution.

From the conclusions arrived at on the consideration that the second sheet of $H^{\cdot}$ ions in the double layer protect the sol from being coagulated by an added electrolyte it is evident that if the amount of adsorption and the valency of several cations are equal, then with the electrolyte of the same anion it is expected that the coagulating power depends greatly upon the diffusion or ionic velocity of the coagulating cation, which enables it to penetrate the Helmholtz double layer and reach the central colloid particle for charge neutralisation. It is well-known that this is the case and comparing the coagulating powers[1] of the chlorides of the univalent cations the following order is obtained with arsenious sulphide sol :—

$H > Cs > Rb > NH_4 > K > Na > Li$, beginning with the cation possessing highest coagulating power. This point is

[1] Compare Physical Properties of Colloid Chemistry by Burton, pages 158—160 (1920).

also highly emphasised by Spring,[1] Pappada,[2] Mukherji[3] and others. It will be interesting here to observe that $H^{\cdot}$ ions can in no way possess a greater attraction for adsorption by the negatively charged As_2S_3 than Cs, Rb, K, etc., because of its acidic nature. For bivalent coagulating ions the order of the coagulating powers is Ba > Sr > Ca, which is the order of their ionic velocities of the cations. In a series of papers[4] from this laboratory we have repeatedly observed that As_2S_3 is not at all a good adsorbent for inorganic cations but has a tendency to adsorb anions like Cl', SO_4'', C_2O_4'', etc.; consequently, we find that keeping the anions same the coagulating powers arrange according to their ionic velocities. If, however, the adsorption of a cation is markedly greater the simple velocity rule, which determines the degree of diffusion, need not be followed.

It is evident that if there exists no other complications, *viz.*, partial stability due to the adsorption of the similarly charged anions or an extra attraction due to a greater amount of adsorption of oppositely charged cations besides that due to the electric charge, the simple valency rule as deduced by Wetham[5] on the basis of the theory of probability is applicable. It is also seen that keeping the valency and the degree of diffusion same for two cations with the same anion, the cation which is adsorbed more will certainly possess greater coagulating power because there is a greater intensity of attraction than that simply due to an electric charge. In the face of these facts, it is unjust to expect from the Schulze-Hardy law that the greater the coagulating power (and therefore valency) of an ion the greater is the amount of its adsorption.

Ishizaka[6] has determined the adsorption and coagulating power of various anions by Al $(OH)_3$ sol. He has observed

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[1] Rec. Trav. Chim. Pays-Bas (2), *4*, 215 (1900).
[2] Koll. Zeit., *6*, 83 (1911).
[3] Gen. Disc. Farad. Soc., 103 (1921).
[4] Compare Ghosh and Dhar, Jour. Phys. Chem., *29*, 435,659 (1925).
[5] Phil. Mag., *48*, 474 (1889). [6] Loc. cit.

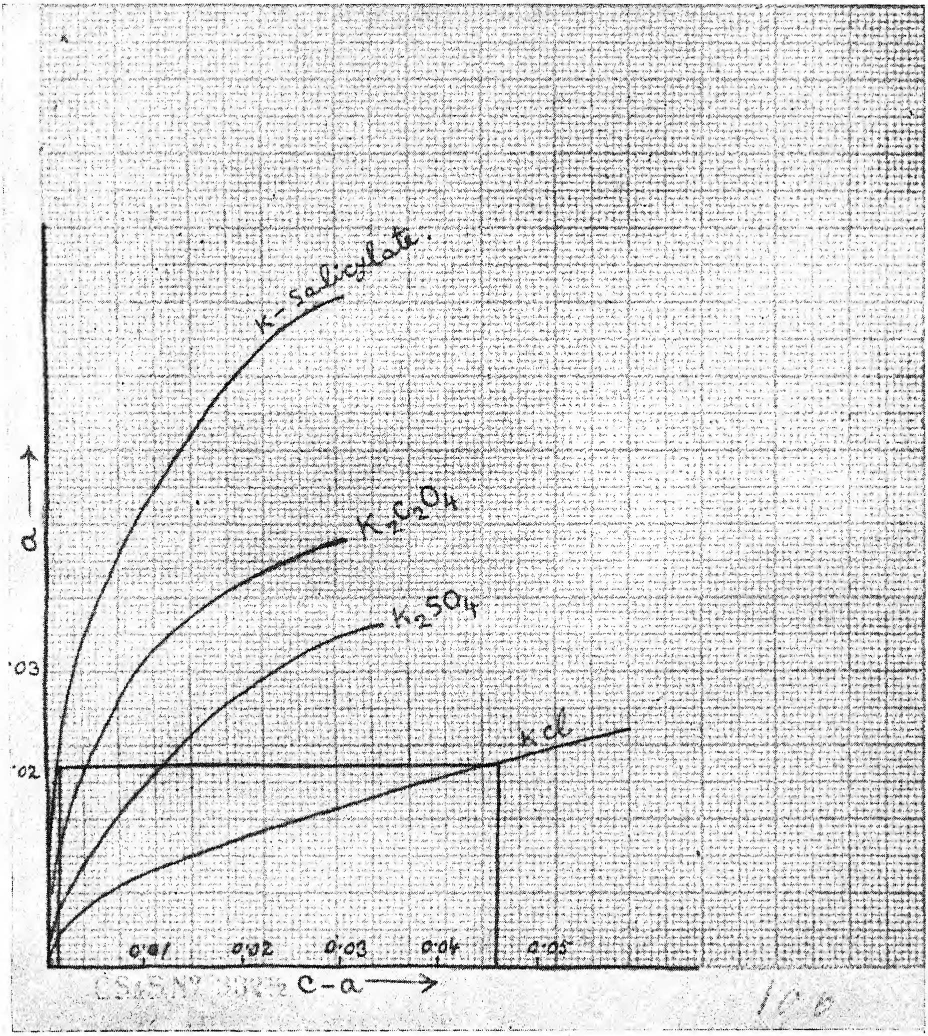
that potassium salicylate is about eight times more effective coagulant than potassium chloride, the precipitation value of the former being 0·0053 M and the latter 0·046 M. The adsorption curves of these anions have also been determined and a closer study of these curves is very interesting. It will be seen that for the concentration (c) 0·046 M the amount of adsorption of the chloride ion is 0·02 millimol (approximately). Now, we find from the curves that 0·02 millimol of salicylate ions are adsorbed when the concentration of the electrolyte is about 0·001 M; and consequently we expect from Freundlich's view that the coagulating power of salicylate ion will be 46 times greater than that of chloride ion. We find, therefore, that salicylate ions are far more adsorbed than chloride ions and the amount of salicylate ions adsorbed is far greater than the actual amount necessary to bring about coagulation. It is well to point out here that the difference between a very high coagulating power as expected from the adsorption curves and that actually observed cannot be ascribed to a difference in ionic velocities of Cl' and salicylate ions, for $H^{\cdot}$ ion, which is about six times faster moving than $K^{\cdot}$ ion, is only twice as more an active coagulant than $K^{\cdot}$ ion for As_2S_3 sol. Another interesting fact observed is that though C_2O_4'' ion is more adsorbed than SO_4'' ion, yet the coagulating power of the former is half to that of the latter.[1] Similar results are obtained with these electrolytes in the coagulation of $Fe(OH)_3$ and $Al(OH)_3$ sols by Weiser.

Freundlich[2] has observed that there can be no comparison with the alkaloids and dyestuffs with cations like $K^{\cdot}$, $Ba^{\cdot\cdot}$, $Al^{\cdot\cdot\cdot}$, etc., when they are adsorbed by arsenious sulphide, because in some cases though the amount of adsorption of these organic cations is 100 per cent, yet the order of the coagulating powers is Ce > Al > Neufuchsin > crystal violet >

[1] The precipitation value of K_2SO_4 is 0·30 millimol per litre and that of $K_2C_2O_4$ is 0·69 millimol per litre.

[2] Kapillarichemie, page 582 (1921).

Opposite to p. 93



quinine sulphate > Morphium chloride > UO_2 > Ba > Mg > p-chloro-anilide > aniline chloride > strychnine nitrate > $K^{\cdot}$ > $Na^{\cdot}$ > $Li^{\cdot}$, beginning with the ion of the highest coagulating power. It will be seen that though $Ce^{\cdot\cdot\cdot}$, $Al^{\cdot\cdot\cdot}$, $Ba^{\cdot\cdot}$ ions, etc., are far less adsorbed than any of the organic cations, the coagulating powers of trivalent ions are greater than all highly adsorbed organic cations. The coagulating powers of bivalent cations like $Ba^{\cdot\cdot}$, $Mg^{\cdot\cdot}$, etc., are also greater than many highly adsorbed substances like strychnine nitrate, aniline chloride, etc.

It is already said in this paper that when an ion carrying an opposite charge is highly adsorbed by a sol its coagulating power is greater because besides an electrostatic attraction the ion possesses an extra attraction due to a chemical affinity for adsorption. It will be observed that for the anions of the same valency like C_2O_4'' and SO_4'' very peculiar results are obtained, for in spite of the fact the amount of adsorption of C_2O_4'' ions is far greater than that of SO_4'' ions, the coagulating power of SO_4'' is greater than C_2O_4'' for $Al(OH)_3$ sol. In view of these facts it is apparent that there is nothing to suggest the view that the greater the amount of adsorption the greater is the coagulating power even with the precipitating ions of the same valency; consequently, it will be rash to expect that this view should also be followed by the ions of varying valency and deduce it directly from the Schulze-Hardy law, which certainly postulates that the valency of an ion is *only* effective in coagulation and there exists no other complications. We have, therefore, suggested in a former paper that extending the Schulze-Hardy law to the phenomenon of adsorption, it is clear that more of an univalent ion is required to coagulate a sol than a bivalent or a trivalent one for purely electrical neutralisation simply because the net charge on a bi- or a trivalent ion is greater than that on the univalent ion.

From a survey of the existing literature on the subject we have shown in the same paper that the experimental results on the phenomenon of adsorption and coagulation generally

point to the fact that the greater the amount of adsorption the less is the coagulating power, which is the true interpretation of the Schulze-Hardy law. Weiser[1] has very recently adversely criticised our interpretation and states on page 962—"In so far as Schulze's law holds, the higher the valence of the ion the greater should be its adsorbability." Weiser has shown in the same paper that provided there exists no other complication the several ions carried down by the coagulum are equivalent and it is easy to percieve that the adsorption values expressed in moles will be only one-third and that of bivalent one-half the adsorption value of a univalent ion, and I have already indicated that this obvious fact—which has been generally overlooked—is demanded by the Schulze-Hardy law, which only considers the valency of an ion and does not entertain complications due to a sort of chemical affinity and consequent high adsorption of the coagulating ion. It must be emphasised here that the valency is the most important factor in determining the coagulating power of an ion. I have already shown that in spite of the fact that Neufuchsin, strychnine nitrate, and morphium hydrochloride are very highly adsorbed by As_2S_3 sol still the lowly adsorbed trivalent coagulating ions $Al^{\cdots}$ and $Ce^{\cdots}$ possess the greatest precipitating powers.

In one of the papers[2] on coagulation and adsorption Weiser in collaboration with Middleton has obtained the following results with $Fe(OH)_3$ sol:

TABLE.*

Anion	Adsorption value		Precipitation value
	Milligram anions	Milli-equivalent anions	
Phosphate ...	0·5721	1·7165	0·875
Citrate ...	0·5018	1·5046	0·500

[1] Jour. Phys. Chem., *29*, 955—965 (1925).

[2] Jour. Phys. Chem., *24*, 630 (1920).

* This table has already been discussed by us (compare Dhar, Sen and Ghosh, loc. cit.). This is again reproduced here to prove that Weiser has incidentally admitted that our generalisation is experimentally sound.

Anion.	Adsorption value.		Precipitation value
	Milligram anions	Milli-equivalent anions	
Tartrate ...	0·6232	1·2464	0·475
Oxalate ...	0·4364	0·8728	0·525
Sulphate ...	0·3804	0·7609	0·485
Iodate ...	0·7512	0·7512	0·600
Dichromate ...	0·1559	0·3110	0·200

In the discussion of their results the above authors remark: "If the ions are arranged in the order of their adsorption values expressed in milli-equivalent anions per gram of the adsorbent the following series is obtained: Phosphate > citrate > tartrate > oxalate > sulphate > iodate > dichromate, phosphate being adsorbed most and dichromate the least. The precipitation values expressed in milli-equivalent per litre would indicate the order of adsorption to be: dichromate > tartrate > sulphate > oxalate > citrate > iodate > phosphate. *It is evident that there is a tendency for ions with the lowest precipitation values to be adsorbed the least and* vice versa, *which is diametrically opposite to what one should expect.*"

It must be emphasised here that the amount of adsorption observed during the process of coagulation occurs in two definite steps. Firstly a coagulating ion is adsorbed for charge neutralisation and secondly the neutral mass may further adsorb the coagulating ion because of some sort of chemical attraction. The average adsorption value of ions in milli-equivalents per gram of an adsorbent is approximately 0·08 for arsenious trisulphide, 0·02 for mercuric sulphide, whilst it is 1·0 in the case of hydroxides like $Fe(OH)_3$, $Al(OH)_3$, $Cr(OH)_3$, etc. It is evident, therefore, that in the case of these hydroxides, the phenomenon of adsorption do not stop with charge neutralisation and a considerable amount of the coagulating electrolyte is taken down by the coagulum because

of chemical affinity. If this second process of adsorption is very high it is difficult to find the general applicability of the view that the ion of the highest coagulating power is adsorbed the least and *vice versa.*

I have already shown from Burton's results that about $\frac{1}{600}$ part of an added electrolyte is only effective in charge neutralisation of a silver sol. I have observed that when manganese-dioxide sol is coagulated by either $AgNO_3$ or $CuCl_2$, the whole of $Ag^{\cdot}$ and $Cu^{\cdot\cdot}$ ions are taken down by the coagulum though only a small portion of the added electrolyte is sufficient to precipitate the sol, whilst enough of $K^{\cdot}$ ions are left unadsorbed when the sol is coagulated by KCl. Here we cannot escape the conclusion that the huge adsorption of $Ag^{\cdot}$ and $Cu^{\cdot\cdot}$ ions has taken place in the second process of adsorption (*viz.*, adsorption after charge neutralisation), for a very small portion of the electrolyte is necessary for charge neutralisation.

Weiser's experiments on the adsorption of oxalate ions by $Cr(OH)_3$ sol indicate that the adsorption of oxalate ions is slightly affected by SO_4'' ions and still less by Cl' ions. Similar results are obtained by Weiser with $Fe(OH)_3$ sol, showing that oxalate ions are very highly adsorbed by the hydroxides. In this connection it is of interest to note that we have already emphasised " that those substances which can form complex salts with the adsorbent are likely to be adsorbed most. Thus Ishizaka has shown that potassium salicylate, potassium ferrocyanide and potassium oxalate are adsorbed most by a sol of aluminium hydroxide. Similar results are obtainable with ferric hydroxide. Evidently the phenomenon of adsorption is most marked when there is some sort of chemical affinity between the adsorbent and the substance, which is being adsorbed." Weiser's own experiment on the adsorption of potassium oxalate by $Cr(OH)_3$ shows that the adsorption of oxalate ions proceeds too far after the sufficient amount has been adsorbed to produce charge neutralisation.

It is apparent, therefore, that a few singular experiments on the huge adsorption of oxalate ions, which is certainly specific and semi-chemical, can in no way be urged as a criticism against our rule (the greater the valency of an ion the less is the amount of its adsorption), which is based on a simple physical conception.

I have already observed in this paper that As_2S_3 is by far a bad adsorbent than $Fe(OH)_3$, $Cr(OH)_3$, $Al(OH)_3$, etc., simply because As_2S_3 do not possess any chemical attraction for cations. Weiser has himself advocated that the adsorption of cations by a sol of As_2S_3 is limited to charge neutralisation and do not entertain any subsequent coagulation. Weiser's own experiments on the effect of adsorption of bivalent $Ba^{\cdot\cdot}$ ions in the presence of many univalent cations show that the adsorption of $Ba^{\cdot\cdot}$ ions is cut down to more than 70% in some cases, showing that univalent ions are adsorbed to a greater degree than bivalent $Ba^{\cdot\cdot}$ ions. On page 964 Weiser has remarked: "Further the results in Table VI furnish almost conclusive proof that the univalent ions are adsorbed more strongly than bivalent barium," which is certainly demanded by our rule already enunciated. It must be said here that the indirect method for comparing the adsorbability for univalent cations is in no way rigid. Moreover it is expected that all the univalent ions are equally adsorbed and it is very difficult to suppose that $H^{\cdot}$ ions are far more adsorbed than $K^{\cdot}$, $Na^{\cdot}$, $Li^{\cdot}$, etc., because arsenious sulphide is acid in nature.

In one of the previous[1] papers from this laboratory it has been shown that hydrated manganese dioxide, which is acid in nature, adsorbs an acid, in a very small quantity, but it markedly adsorbs cations when shaken with a neutral salt solution and a considerable amount of acid is liberated. Several workers on the phenomenon of adsorption have observed that this selective adsorption of an ion from an

[1] Compare Chatterjee and Dhar, Koll. Zeit, *33*, 18 (1923).

electrolyte produces either acid or alkali in the filtrate. Glixelli[1] has observed an augmentation of the acidity of silica gels under the influence of neutral salts. Weiser[2] has shown that on shaking $Cu(OH)_2$ precipitate with a neutral salt alkali is set free due to the preferential adsorption of an anion. We have observed that $BaSO_4$ markedly adsorbs an anion from an electrolyte leaving the cation free, which develops alkalinity. Very recently Frankfert and Wilkinson[3] have shown the cupric ferrocyanide develops acid or alkali according to the degree of adsorption of a cation or an anion.

In an attempt to explain the phenomenon of soil acidity, Mukherjee[4] has observed that this phenomenon is due to the primary adsorption of an anion, which gives negative charge to the surface. The liberation of acid in an extract with a neutral salt has been ascribed to the displacement of $H^{\cdot}$ ions from the second sheet. In a very recent paper Mukherji[5] has given the following formula to explain the acidity developed with the system BA with adsorbed acids:

$$\underset{\text{I}}{[(BA)_x\,(H_2O)_y\,\bar{A}\,]H^+} + KCl \rightleftharpoons \underset{\text{II}}{[(BA)_x\,(H_2O)_y\,\bar{A}]\,K^+} + HCl$$

It is assumed that the acid is liberated due to the replacement of $H^{\cdot}$ ions by $K^{\cdot}$ ions in the second sheet and there is no change between the substance I and II, even in their electric charge. The fundamental difficulty in accepting this formula is that it cannot explain the phenomenon of charge neutralisation and charge reversal. It has been already remarked that the precipitated arsenious sulphide is held in the colloidal stage due to the marked adsorption of HS' ions from the weak acid

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[1] Compt. rend., *176*, 1714 (1923).

[2] Jour. Phys. Chem., *27*, 501 (1923).

[3] Ibid., *28*, 651 (1923).

[4] Phil. Mag., *44*, VI (340).

[5] Journ. Ind. Chem. Soc. (1925).

H_2S and it has been shown that the liberation of an acid is due to the diminution of the negative charge of the colloid, when $H^{\cdot}$ ions bound in the double layer are set free; consequently this view is essentially different from that of Mukherjee and can satisfactorily explain the fall in the electric charge or reversal in charge, phenomenon actually observed by the experiments.

It must be emphasised here that the specific adsorption of a cation or an anion develops acidity or alkalinity and certainly depends upon the chemical nature of the adsorbent. For example, substances like SiO_2, MnO_2, etc., are generally charged negatively due to the adsorption OH' ions and can adsorb a considerable amount of cations than anions and develop acidity, because SiO_2, MnO_2, etc., are acidic in nature; whilst substances like $Fe(OH)_3$, $Cr(OH)_3$, $Al(OH)_3$, etc., are positively charged due to the adsorption of $H^{\cdot}$ ions and can adsorb mainly the anions from the added electrolyte leaving the filtrate alkaline, because these substances are basic in nature.

We have already stated in a previous paper "that charge reversal, amount of adsorption and complex formation go hand in hand and depend upon the chemical affinity existing between the adsorbent and the substance which is being adsorbed." It is, therefore, highly essential that a theory connected with the specific adsorption of ions by the precipitated substances must take into account the chemical nature of the adsorbent and of the adsorbed ions.

Summary.

1. The phenomenon of coagulation depends upon four factors, *viz.*, (*a*) The valency of the oppositely charged ion, (*b*) the adsorbability of the oppositely charged ion, (*c*) the adsorbability of the ion bearing the same charge as the colloid particles, and (*d*) the rate of diffusion or the ionic velocity of the coagulating ion.

2. An explanation based on the protective effect of Helmholtz double layer has been advanced to explain the existence of a minimal concentration of electrolytes necessary for the coagulation of colloids.

3. It is shown that the amount of adsorption associated with the charge neutralisation of a colloid is very small. If, however, there is some sort of chemical affinity between the adsorbent and the substance to be adsorbed, the amount of adsorption is abnormally large.

4. It is emphasised that the general rule that the greater the valency of an ion the greater is its amount of adsorption is not true and cannot be deduced from the Schulze-Hardy law.

5. The true interpretation of the Schulze-Hardy law is that the greater the valency of an ion the less is the amount of its adsorption and *vice versa*. Weiser's own experiments with $Fe(OH)_3$ and As_2S_3 sols corroborate our view.

6. It is suggested that a substance of an acid character generally develops acidity when shaken with a neutral salt due to the preferential adsorption of a cation, whilst a substance of a basic character develops alkalinity when treated with neutral salt due to a greater amount of preferential adsorption of an anion.

My best thanks are due to Professor N. R. Dhar, D.Sc., F.I.C., for his kind interest and advice.

ELECTROLYTE ANTAGONISM WITH INORGANIC SUSPENSIONS AND THE EQUILIBRIUM BETWEEN SODIUM AND CALCIUM IONS IN BIOLOGICAL SYSTEMS

BY

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In a previous paper[1] I have shown that the stability of a colloidal solution depends to a large extent on the amount of impurity present and also on the concentration of the sol. Thus with a sol of ferric hydroxide, the stability gradually increases with the increase in the hydrochloric acid content. With a suspension of aluminium hydroxide, the stability also increases with the increase in the concentration of the peptising acid, and in both the cases the stability ultimately reaches a maximum. This fact has been explained by the view that the first stabilisation is due mainly to the adsorption of H° ions from the acid, but gradually with the increase in the concentration of the acid, the concentration of the negative ion in the solution increases and exerts a coagulating effect. Also the adsorption of H° ions by the particles of the suspension has been found to reach a maximum and hence owing to the balancing of these factors, a maximum in stability soon occurs. In another paper[2] it has been shown that the same relations hold in the case of chromium hydroxide sol. With the gradual addition of hydrochloric acid, colloidal chromium

[1] K. C. Sen : Jour. Phys. Chem., *28*, 1029 (1924).
[2] K. C. Sen and M. R. Mehrotra : Zeit. Anorg. Chem., *142*, 345 (1925).

Allahabad University Journal, Vol. I, p. 367 (1925).

hydroxide becomes more and more stabilised towards KCl, K_2SO_4 and $K_2C_2O_4$, but in the last two cases, the stability soon reaches a maximum. With a mixture of the electrolytes K_2SO_4 and $K_2C_2O_4$, no stabilising influence of any one of the electrolytes was observed. With all these three hydroxides, it has been found that dilution of the colloid makes it less stable towards all electrolytes irrespective of the valency of the precipitating ions. It has further been shown that the gradual addition of potassium ferrocyanide to a sol of copper ferrocyanide made it more stable towards both monovalent and bivalent precipitating ions, but the stability soon reaches a maximum also. It was also observed that the nature of the stabilisation observed in the case of copper ferrocyanide sol in presence of $K_4Fe(CN)_6$ is similar to that observed by other investigators in the case of As_2S_3 sol and KCl, LiCl or HCl. This is also the case with mastic, As_2S_3, HgS and CuS sols in presence of OH' ions, and $Fe(OH)_3$, $Al(OH)_3$ and $Cr(OH)_3$ sols in presence of acids. The view was put forward that in the majority of cases studied, the so-called antagonistic effect between pairs of salts is really due to the stabilising effect of the ions having the same charge as the colloid particles themselves possess. It was also observed that in no case it has been proved definitely that the antagonistic effect is purely cationic, but it is probable that in some cases a joint action of the anionic and cationic effect may have been observed. From the results obtained it was thought probable that the stabilisation of some colloids on dilution, the antagonistic action between pairs of some electrolytes on several colloids, and the phenomenon of acclimatisation observed with some sols, may be explained by the same theory, and in all these cases, the importance of the ion having the same charge as on the colloid particles, will have to be recognised as one of the primary factors.

From a consideration of the importance of the same-charged ion in colloid coagulation, it has been suggested in

another paper, that with positively charged sols like Fe $(OH)_3$, etc., electrolytes giving an acid reaction in water, and having easily adsorbable cations will show considerable antagonistic action to other coagulating electrolytes. Thus it was mentioned that mixtures of electrolytes like $FeCl_3$ and KCl, etc., will show considerable antagonistic action in the coagulation of a ferric hydroxide sol. It was further stated that with a sol of arsenious sulphide, mixtures like $KCl + K_4\ Fe\ (CN)_6$, etc., will also show an antagonistic action. Both these anticipations have been realised. In a recent paper Freundlich and Wosnessensky[1] have shown that a sol of ferric hydroxide is considerably stabilised towards KCl if ferric chloride, aluminium chloride or lanthanum nitrate is present. It has been found by Ghosh and Dhar in this laboratory that there exists a considerable antagonism when the salt pair $Al\ (NO_3)_3 + K_2SO_4$ is used for the coagulation of the ferric hydroxide sol. In the following table the results are shown.

TABLE I.

Sol—3·62 gr. Fe_2O_3 per litre.
Electrolytes: $Al(NO_3)_3 + K_2SO_4$.

$Al\ (NO_3)_3N$ taken in c.c.	K_2SO_4 N/400 required for coagulation. Observed.	Calculated.	Difference.
0	1·45	—	—
0·2	1·8	1·32	0·48
0·5	1·75	1·13	0·62
0·8	1·65	0·95	0·7
1·6	1·35	0·44	0·91
2·3	0	—	

From the above results it will be observed that the pair $Al\ (NO_3)_3 + K_2SO_4$ does not show any additive relation

[1] Kolloid Zeit., *33*, 222 (1923).

with regard to the precipitating power of the individual salts on a positively charged ferric hydroxide sol. These experiments are thus extensions of the work done with mixtures of acids and salts. Again it has been found by J. N. Mukherjee and B. N. Ghosh[1] that there exists a considerable antagonism when salt pairs like $KCl + K_4Fe(CN)_6$ are used in the coagulation of arsenious sulphide sol. In the following table, the results obtained have been recalculated from the original data.

TABLE II.

Electrolytes : $KCl + K_4Fe(CN)_6$.

Concentration of $K_4Fe(CN)_6$ in normality taken.	Concentration of KCl in normality for coagulation.		Difference.
	Observed.	Calculated.	
0	0·07	—	—
0·04	0·0735	0·2560	·0175
0·066	0·0651	0·0469	·0182
0·10	0·0567	0·035	·0217
0·133	0·0371	0·0235	·0136
0·20	0	—	—

It will thus be observed that *the so-called antagonistic action of electrolytes can be shown in the case of practically all colloids provided we choose suitable ion pairs, one ion of which goes to stabilise the sol.* Hence the general statement that adsorption of same-charged ions stabilises a suspension towards some coagulating ions is undoubtedly true and has been completely supported by the recent investigation of Mukherjee and Ghosh (loc. cit.) who have also found that pairs of electrolytes like sodium benzoate $+ BaCl_2$, sodium benzoate $+ CaBr_2$, sodium acetate $+ NaCl$, sodium benzoate $+ NaCl$, etc.,

[1] Jour. Indian Chem. Soc., *1*, 213 (1924).

show this antagonistic behaviour in the coagulation of arsenious sulphide sol.

In the previous paper it was suggested that this stabilisation is in the majority of cases due to the adsorption of some negative ions which in low concentrations increase the charge on the colloidal particles. Though no actual experiment on the amount of electrical charge carried by the colloid particles under these conditions has been made in the case of colloidal arsenious sulphide, a consideration of several allied cases show that this is probably true. Thus in the case of some oil-in-water emulsions, it has been found by Ellis,[1] Powis[2] and others, that at low concentrations of KCl or LiCl, the negative charge on the oil drops is appreciably higher than when these electrolytes are absent. Some results obtained by Loeb[3] of the effect of electrolytes on a negatively charged collodion suspension show that here also there is an initial rise in the amount of electrical charge on the colloid particles on the addition of low concentration of some electrolytes. Consequently the view that negative ions at some concentrations may increase the effective charge of a colloidal surface seems to be well established and hence the explanation which has been given in the previous paper to account for the stabilisation of the sols in presence of a mixture of electrolytes is justified. In the case of positively charged sols there is no difficulty, for it is well known that the addition of traces of acids or positive ions of high valence usually increase the mobility of the colloid particles in an electric field.

In some previous papers[4] I have shown that dilution of some negatively charged sols like arsenious sulphide and antimony sulphide makes them more stable towards some

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[1] Zeit Physik Chem., *80*, 597 (1912).
[2] Zeit Physik Chem., *89*, 186 (1915).
[3] Jour. Gen. Physiol, *5*, 109 (1922).
[4] Jour. Phys. Chem., *28*, 313 (1924).
Kolloid Zeit., *34*, 262 (1924).

monovalent coagulating ions. The explanation has been given that the negative ion has a great effect when the coagulating ion is monovalent, and the abnormality is due to the stabilising action of this negative ion. If this be the case, it was thought probable that the antagonistic action between electrolytes would be more pronounced on a diluted sol than on a concentrated sol of arsenious sulphide. In the following pages, the experimental results obtained have been given. It will be observed that the expectation has been realised.

EXPERIMENTAL PART.

Colloidal arsenious sulphide was prepared in the usual way by passing hydrogen sulphide through distilled water in which a solution of arsenious acid was added drop by drop. The excess of hydrogen sulphide was then removed by a current of pure hydrogen. The method adopted to determine the coagulation point was the same as described in the previous paper. 5 c.c. of the sol has been used in each experiment, the total volume of the sol + electrolyte being always 10 c.c. and one hour was allowed for the coagulation to take place. The concentration of the original sol is 3·4 grams As_2S_3 per litre.

TABLE III.

Original sol. Electrolytes: $NaCl + CaCl_2$.

NaCl M/2 taken in c.c.	$CaCl_2$ M/200 required for coagulation.		Difference.
	Observed.	Calculated.	
0	1·3	—	—
0·3	1·75	1·08	0·67
0·5	1·8	0·94	0·86
0·8	1·6	0·72	0·88
1·0	1·3	0·58	0·72
1·2	1·0	0·44	0·56
1·8	0	—	—

TABLE IV.

$\frac{1}{2}$-diluted sol. Electrolytes: $NaCl+CaCl_2$.

NaCl M/2 taken.	$CaCl_2$ M/200 required.		Difference.
	Observed.	Calculated.	
0	1·25	—	—
0·3	1·9	1·07	0·83
0·5	2·0	0·95	1·05
0·8	1·95	0·77	1·18
1·0	1·8	0·64	1·16
1·5	1·0	0·35	0·65
2·05	0	—	—

TABLE V.

Original sol. Electrolytes: $KCl + CaCl_2$.

KCl M/2 taken.	$CaCl_2$ M/200 required.		Difference.
	Observed.	Calculated.	
0	1·3	—	—
0·3	1·75	1·04	0·71
0·5	1·7	0·86	0·84
0·8	1·4	0·604	0·796
1·0	1·0	0·43	0·57
1·2	0·65	0·26	0·39
1·5	0	—	—

TABLE VI.

$\frac{1}{2}$-diluted sol. Electrolytes: $KCl + CaCl_2$.

KCl M/2 taken.	$CaCl_2$ M/200 required.		Difference.
	Observed.	Calculated.	
0	1·25	—	—
0·3	1·85	1·02	0·83
0·5	1·9	0·87	1·03
0·8	1·7	0·65	1·05
1·0	1·35	0·49	0·86
1·2	0·9	0·34	0·56
1·65	0	—	—

TABLE VII.

Original sol. Electrolytes: $NaCl + BaCl_2$.

NaCl M/2 taken.	$BaCl_2$ M/200 required.		Difference.
	Observed.	Calculated.	
0	1·2	—	—
0·3	1·65	1·0	0·65
0·5	1·75	0·86	0·89
0·8	1·5	0·66	0·84
1·0	1·25	0·53	0·72
1·8	0	—	—

TABLE VIII.

$\frac{1}{2}$-diluted sol. Electrolytes: $NaCl + BaCl_2$.

Na Cl M/2 taken.	$BaCl_2$ M/200 required.		Difference.
	Observed.	Calculated.	
0	1·15	—	—
0·3	1·75	0·98	0·77
0·5	1·85	0·87	0·98
0·8	1·7	0·70	1·0
1·0	1·6	0·59	1·01
1·5	0·8	0·31	0·49
2·05	0	—	—

TABLE IX.

Original sol. Electrolytes: $KCl+BaCl_2$.

KCl M/2 taken.	$BaCl_2$ M/200 required.		Difference.
	Observed.	Calculated.	
0	1·2	—	—
0·3	1·75	0·96	0·79
0·5	1·7	0·80	0·90
0·8	1·45	0·56	0·89
1·0	1·1	0·40	0·70
1·2	0·75	0·24	0·51
1·5	0	—	—

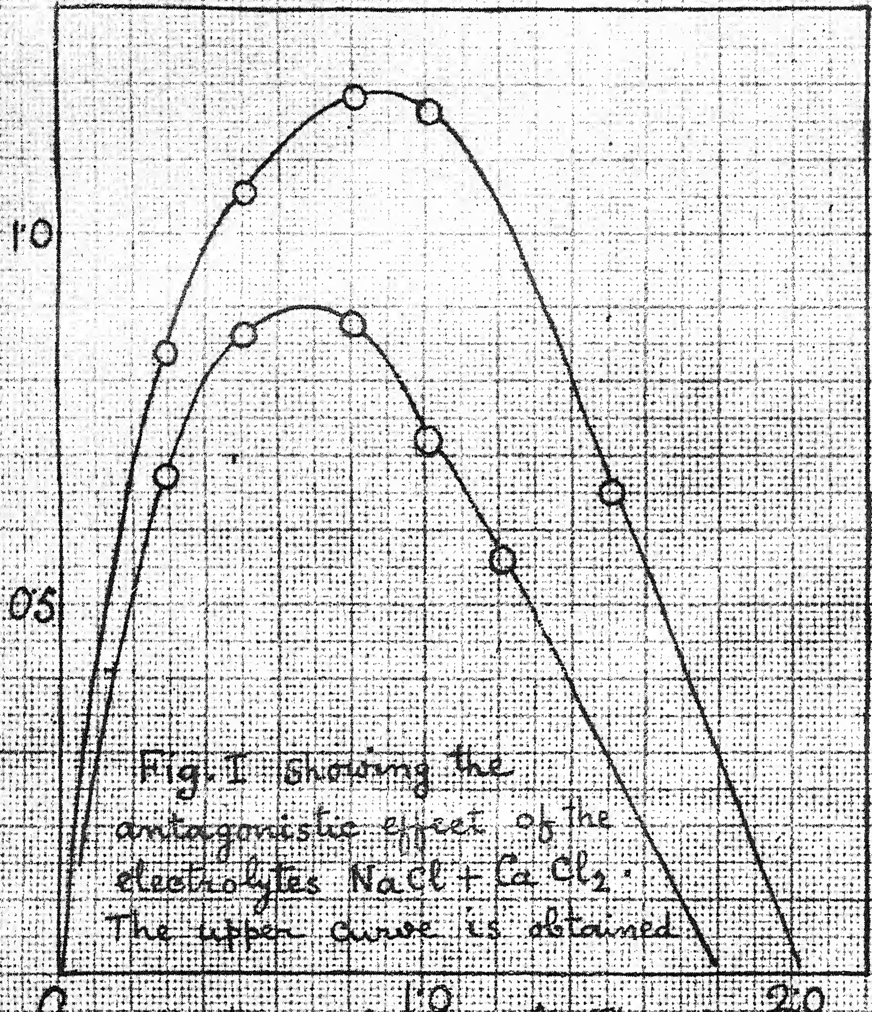

Fig. I Showing the antagonistic effect of the electrolytes $NaCl + CaCl_2$. The upper curve is obtained with the diluted sol. The abscissa represents the amount of uni-univalent salt taken in c.c. and the ordinate represents the difference in the observed and the calculated values of the divalent electrolyte required for coagulation. The difference in the stabilisation of the original and the diluted sol is quite marked.

TABLE X.

$\frac{1}{2}$-diluted sol. Electrolytes: $KCl+BaCl_2$.

KCl M/2 taken.	$BaCl_2$ M/200 required.		Difference.
	Observed.	Calculated.	
0	1·15	—	—
0·3	1·8	0·94	0·86
0·5	1·8	0·80	1·0
0·8	1·55	0·59	0·96
1·0	1·25	0·45	0·80
1·2	1·95	0·31	0·64
1·65	0	—	—

The last two tables are not to be strictly compared with other tables, as a little portion of the solid matter got deposited due to an ageing effect of the sol. It will however be noticed that the antagonistic effect is more pronounced in all cases with diluted sols. In the accompanying curves the results given in Tables III to X are shown. The Figures 1, 2, 3 and 4 respectively give the results with pairs $NaCl+CaCl_2$, $KCl+CaCl_2$, $NaCl+BaCl_2$, and $KCl+BaCl_2$. The abscissa represents the amount of the uni-univalent salt taken in c.c., and the ordinate represents the difference in the observed and the calculated values of the divalent electrolyte required for coagulation.

Figures 1, 2, 3 and 4.

The upper curves are always those obtained with diluted sols. Hence it appears that the negative ions have more effect on a diluted sol than on a concentrated sol, and therefore the explanation offered in the case of arsenious sulphide sol which behaves abnormally on dilution towards some univalent precipitating ions seems to be true.

THEORETICAL PART.

Several years ago, Clowes[1] in an exhaustive paper entitled "Protoplasmic Equilibrium," discussed the antagonistic action of electrolytes, specially that between sodium chloride and calcium chloride observed in the case of emulsions, sols, jellies and physiological systems such as protoplasmic equilibrium, clotting of blood plasma, etc. This paper was not referred to in my previous communications as it was not known to me at that time; but the ideas expressed are so remarkable, and the conclusions regarding the mechanism of the antagonistic action of electrolytes are so similar to that drawn by me independently from my experiments, that a further discussion regarding the antagonistic action of electrolytes in the growth of cell life and in the stabilisation of a typical inorganic suspension like arsenious sulphide sol seems desirable. Since in biological studies we have mainly to do with an equilibrium between sodium chloride and calcium chloride, this pair has been chosen to show the antagonistic effect on arsenious sulphide sol in the present paper. Before however any comparison is made, I will briefly refer to the electrolyte antagonism as observed in physiological systems.

From the data accumulated on this subject by S. Ringer,[2] J. Loeb,[3] R. Lillie[4] and other biologists, it has long been recognised that mineral salts are individually toxic for the cell when used at sufficient concentration, but that a favourable medium is afforded for the maintenance of cell life when certain salts are used collectively, preferably in those approximately fixed ratios in which they occur in nature. For example, certain marine organisms are instantly killed when transferred from sea-water to a solution of NaCl containing that substance

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[1] Jour. Phys. Chem., *20*, 407 (1916).

[2] J. Physiol., *11*, 369 (1890); *13*, 300 (1892).

[3] "Artificial Parthenogenesis and Fertilisation," 1913: "The Mechanistic Conception of Life," 1912.

[4] Am. Jour. Physiology, *29*, 372 (1912).

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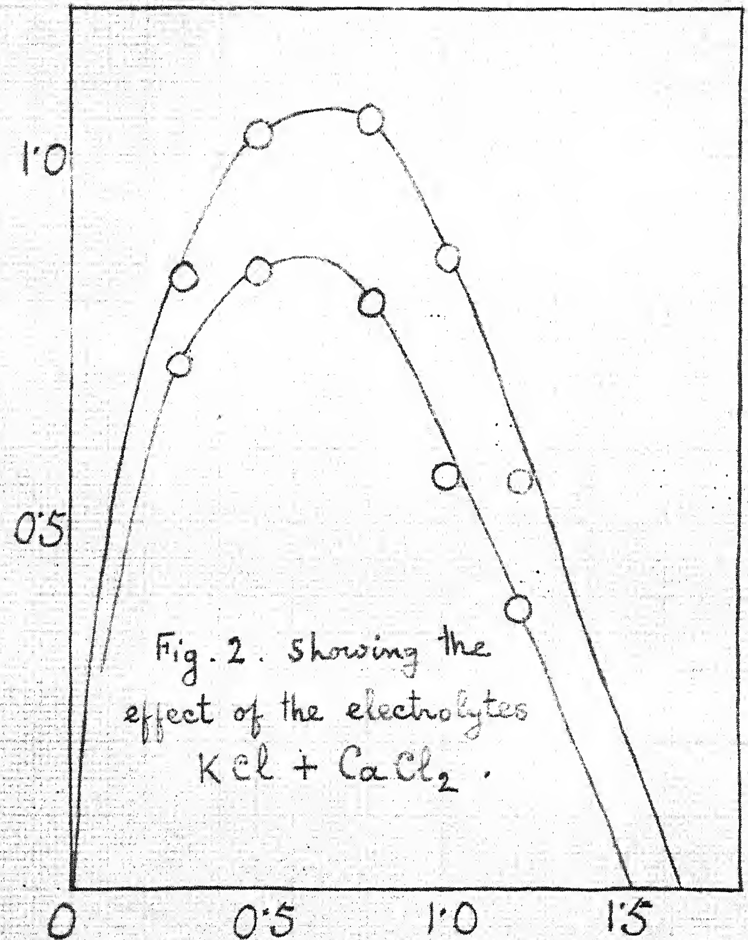


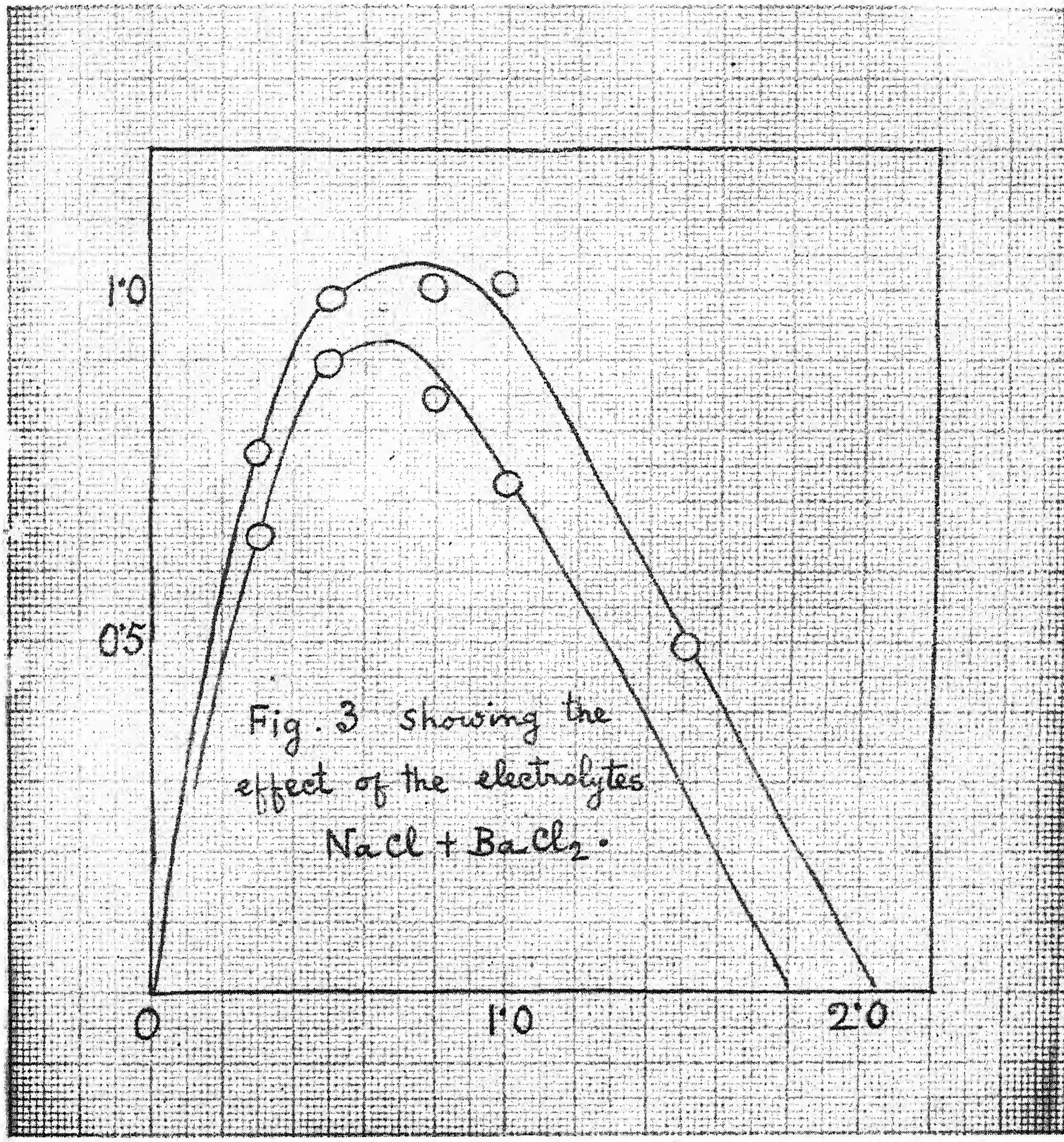
at the concentration at which it occurs in sea-water, but may be protected against the destructive effect of the NaCl by the addition of $CaCl_2$, in a proportion of one or two molecules of the latter to 100 of the former. This ratio of 100 molecules of NaCl to one or two of $CaCl_2$ is peculiarly significant in view of the fact that this is the ratio in which NaCl and $CaCl_2$ tend to occur in nature, in sea-water, in the blood of mammals, etc. Osterhout[1] has demonstrated that wheat grown in an aqueous solution containing 0·12 M NaCl + 0·0012 M $CaCl_2$ developed extensive rootlets and showed other signs of healthy growth and activity, but that in control experiments in which either a 0·12 M NaCl or a 0·12 M $CaCl_2$ solution was employed, virtually no growth occurred. Similarly zoöspores of vaucheria grew rapidly in a mixture containing 0·01M NaCl + 0·0001 M $CaCl_2$, or even in pure distilled water, but failed to show any signs of growth in solutions containing either 0·01 M NaCl or 0·01 M $CaCl_2$. Osterhout has published an interesting series of experiments on the influence exerted by various electrolytes on the conductivity of Laminaria tissues. The tissues tested immediately after removal from sea-water appeared to exhibit a practically constant resistance to the passage of an electric current, but after exposure to a comparable solution of NaCl a markedly diminished resistance was noted; after exposure to a comparable $CaCl_2$ solution a markedly increased resistance was exhibited, at least for a short period; but no appreciable variation from the normal occurred after exposure of the tissues to properly balanced mixtures containing NaCl and $CaCl_2$ in ratios of 100 molecules of the former to one or two of the latter. Osterhout naturally concluded that NaCl increases and $CaCl_2$ diminishes the permeability of the tissues to the passage of water and water-soluble ions, and that, in those solutions in which no change in conductivity occurs, the destructive effect of NaCl is exactly counterbalanced by the protective effect of $CaCl_2$.

[1] Plant World, *16*, 129 (1913); Jour. Biol. Chem., *19*, 335 (1914); Science, *41*, 255 (1915).

In summarising the above data Clowes observes that since a large variety of marine and other organisms are killed by solutions of NaCl on the one hand or $CaCl_2$ on the other, but may be kept alive in appropriate mixtures of NaCl and $CaCl_2$, and under certain circumstances, may even be transferred without injury to distilled water, and since $CaCl_2$ diminishes and NaCl increases the permeability of the protoplasmic system, it may well be concluded that the $CaCl_2$ exerts its destructive effect on protoplasm by causing the formation of a protoplasmic film or membrane too impermeable for the performance of normal vital functions while NaCl exerts the reverse effect, interfering with the formation of a film or rendering the film already formed too permeable. The maintenance of vital processes may well depend upon the production of a protoplasmic film or membrane capable of exhibiting variations in permeability within comparatively narrow limits, just as the maintenance of function of an engine or machine depend upon an accurately regulated valve system. Osterhout has demonstrated that the tissues of marine organisms may be made to undergo repeated variations in permeability within certain limits without apparent injury, by short alternating exposures to solutions of NaCl and $CaCl_2$. It must be concluded, therefore, that the protoplasmic film is a physical system capable of undergoing reversible variations in permeability as a result of exposure to solutions containing varying proportions of salts of Na and Ca.

In order to realise such reversible variations in permeability in purely physical systems, Clowes determined the antagonistic effect of several salt pairs on the stability of an emulsion system. It was noted that a marked analogy exists between the transformation of an emulsion of oil-in-water into an emulsion of water-in-oil, or of blood plasma into a blood clot, or of a casein suspension into a casein clot. In all the three cases, salts of Ca promote and alkalis and salts of Na inhibit the transformation of a

Opposite to p. 109



system consisting of a non-aqueous phase dispersed in water into the reverse type of system, consisting of water more or less perfectly dispersed in a non-aqueous phase. The experiments of Clowes consisted firstly in determining the ratio of NaCl to $CaCl_2$ in which an oil-in-water emulsion retains its original condition in presence of this mixture of electrolytes, and secondly by allowing an oil to flow in water in presence or absence of any electrolyte, to count the number of drops obtained from a given volume of the oil. The balancing point of a mixture of electrolytes was reached when the number of drops was just the same as obtained by using water alone in the absence of either of the electrolytes. From the results he observed that when the antagonistic electrolytes in question are present in certain balanced ratios, a critical point occurs, and the ratio in which given electrolytes exert a compensatory effect on one another, as indicated by the point at which the number of drops corresponds with that of the original system, is almost invariably the same as that at which the electrolytes in question exert antagonistic or compensatory effects on one another in biological systems. Thus for example, NaCl which increases the number of drops, and $CaCl_2$ which diminishes the number of drops, appear to balance one another in a ratio of 100 molecules of the former to one or two of the latter according to concentration, these ratios being approximately the same as those in which the salts in question occur in sea-water, the blood of mammals, etc.

From the above discussion it will appear that an oil-in-water emulsion is quite comparable to the protoplasmic system and a close correspondence exists in some of the physical properties. It would be obviously a matter of great interest to enquire whether a similar quantitative analogy can be shown to exist in the case of inorganic suspensions like arsenious sulphide sol. That NaCl antagonises $CaCl_2$ in the coagulation of this sol, has been shown in the previous pages. In order however to complete the analogy,

it is necessary to show that the ratio of the concentrations of these salts at the balancing point is the same as obtained in the biological cases previously cited. In order to obtain such data, the following method has been adopted. It will be observed from Table III, that the suspension of As_2S_3 is coagulated by 1·3 c.c. $CaCl_2$ M/200 when there is no NaCl present. This point can therefore be considered as the original stability point of the colloid. When 0·3 c.c. NaCl M/2 is present, the amount of $CaCl_2$ required for coagulation is 1·75 c.c., *i.e.*, 0·45 c.c. in excess of that required to coagulate the original colloid. We can consider therefore that the original stability of the colloid is reached when NaCl and $CaCl_2$ are present in quantities of 0·3 and 0·45 c.c. each respectively. This appears to be the balancing point in the stability of the colloid. On calculating from the above figures, the results come out to be in the ratio of 100 molecules of NaCl to 1·5 molecules of $CaCl_2$. From the second data in the same table, the ratio comes to 100 molecules of NaCl to one molecule of $CaCl_2$. From the first three data in Table IV, the molecular ratios of NaCl to $CaCl_2$ are, 100 : 2·1, 100 : 1·5 and 100 : 0·9 respectively. It will appear from the data that the ratio increases with the increase in the initial NaCl concentration. For apparent reasons, the calculation cannot be made for other data in the tables. (Under the conditions of the experiment, the system is not reversible as we obtain in the case of emulsions, and hence an exact similarity with the oil-in-water emulsions is not to be expected.) But the remarkable coincidence in the value of this ratio at least within certain concentrations in the case of such diverse systems as arsenious sulphide suspension, emulsions and protoplasmic systems justifies the contention of Clowes that we are really dealing with the existence of some heretofore unappreciated fundamental physical principle. Since in all these systems, the only general condition is the concentration of negative ions on the surface of one phase in the case of

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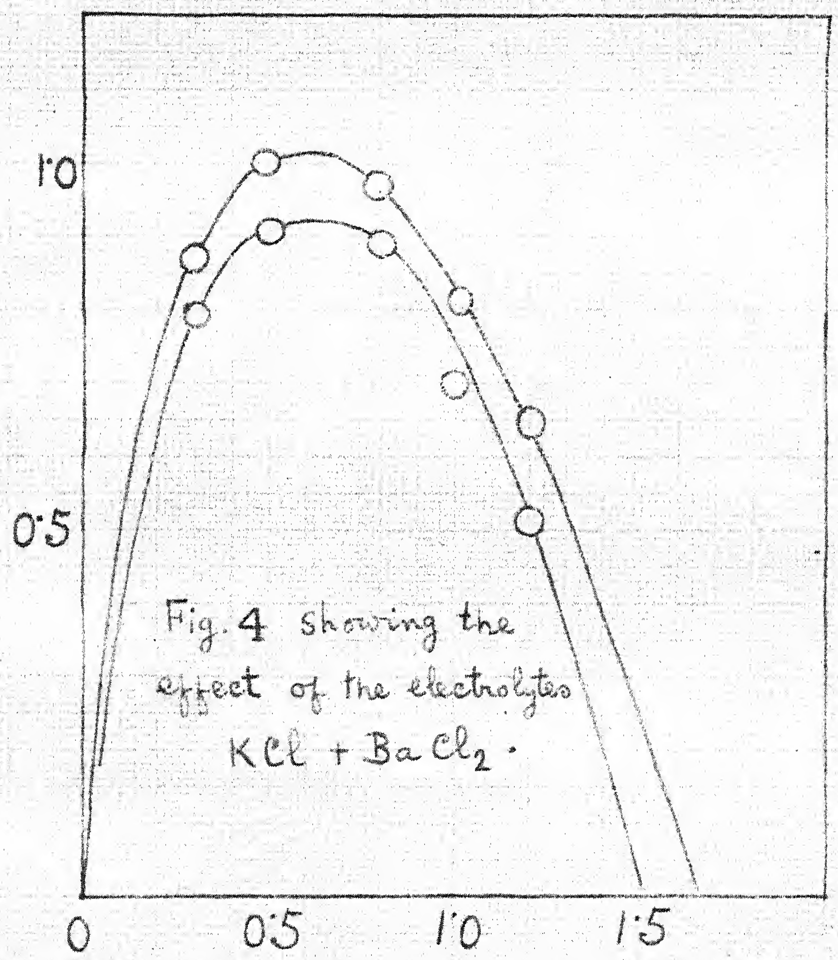

NaCl or the concentration of positive ions in the case of $CaCl_2$, it is very likely that this factor of importance is the electrical charge on the dispersed phase.

In a recent book,[1] Höber gives a large number of ratios of antagonistic action of different salt pairs. Thus from experiments on deplasmolysis, Netter concludes that the antagonistic action of bivalent and univalent salts is about neutralised when the ratios of sodium to other cations are: Ca 75; Sr 40—50; Ba 5—10; Co and Ni 50; Mn 5 and $Co(NH_3)_6$ 40. In some cases as with certain sea algae the phenomenon is primarily due to the swelling of the membrane, and in one case of this sort the neutral ratio of sodium to calcium was 250. Loeb found that with the eggs of *Fundulus* there is a mutual antagonism between sodium chloride and potassium chloride. I do not know under what conditions this pair will show antagonistic behaviour in the coagulation of arsenious sulphide sol. Experiments have been done which show that there is practically no antagonistic action when this mixture is used with a sol of arsenious sulphide. It has however been shown already that like NaCl, KCl also antagonises the coagulating action of $CaCl_2$ on arsenious sulphide suspension. It has been found possible by Clowes, by using drop systems containing a large amount of oleic acid in conjunction with sodium oleate, to produce similar somewhat feeble antagonistic effects between NaCl and KCl.

Since it has been shown in previous pages that by choosing suitable salt pairs, we can show the antagonistic effect on practically every diphasic system, it follows that we can group electrolytes in two main divisions according as the suspension is positively or negatively charged. When the suspension is positively charged, easily adsorbable positive ions like H° or trivalent or quadrivalent metal ions like $Fe^{\circ\circ\circ}$, $Al^{\circ\circ\circ}$

[1] Physikalische Chemie der Zelle und der Gewebe, Part II (1924), pp. 662, 668.

$Th^{\circ\circ\circ\circ}$, etc., will increase the dispersion of the sol, and hence the stability of the system towards negative coagulating ions. If the suspension is negatively charged, the presence of adsorbable negative ions like bivalent or trivalent anions and salts of Na, K or alkalis will tend to increase the dispersion, and hence increase the stability. Clowes only considered the latter case, as this is analogous to biological systems and hence his conclusions are somewhat limited. The general principle may therefore be stated thus: *If any ion having the same charge as the colloid particles themselves possess is adsorbed more, or is concentrated in excess in the interface between the two phases at least at some concentrations of the electrolyte, it will tend to increase the charge and the dispersion of the suspension, and hence will antagonise the effect of the oppositely charged coagulating ion already present in or added to the system. If on the other hand the oppositely charged ion is concentrated in excess, we may have either coagulation, charge-reversal or in the case of emulsions, an inversion of phase under suitable circumstances. The final equilibrium will thus depend on a balance of cations on the one hand, and anions on the other hand.* Both the terms "colloid" and "coagulating" are used here in their widest sense. I believe that this marks an advance in our previous knowledge, as we can now correlate a large number of facts with this simple theoretical conception. The present views thus bring together all cases of suspensions, both negatively and positively charged, and also those suspensions which are stabilised by the presence of an interfacial film, and we can thus predict a large number of possible cases of ionic antagonism in diphasic systems.

In conclusion a brief reference may be made to the structure of the protoplasmic system[1] as evidenced from these physical considerations. It is well known that the coagulation

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[1] For a fuller discussion, compare the paper of Clowes (*loc. cit.*).

of inorganic suspensions like arsenious sulphide sol is usually irreversible under ordinary conditions. The reversible variations in permeability in presence of salts of the protoplasmic system therefore point to a closer analogy with emulsion systems which are also freely reversible, than to inorganic suspensions. "The active Brownian movement exhibited when protoplasm is examined by means of the ultramicroscope indicating colloidal particles dispersed in water, and the facility with which water-soluble substances penetrate protoplasm when they have passed the protoplasmic film, suggest the possibility that the original protoplasmic structure approximates to a dispersion of proteins, lipoids, fats and other non-aqueous constituents in water. The resistance offered by the protoplasmic film to the passage of salts, sugars and other simple water-soluble substances, the difference in the proportions of certain electrolytes within and without the cell, the phenomena of osmotic pressure, and resistance to the passage of an electric current all support the view that, at least under certain conditions, water communications through the protoplasmic film are somewhat limited, and suggest the possibility that the protoplasmic film may approximate to the reverse type of system in which water is more or less dispersed in the non-aqueous constituents of protoplasm. The freedom with which anesthetics and other substances miscible with or soluble in fats and lipoids penetrate the cell is a further argument in support of the contention that a fatty or a lipoid film constitutes, at least under certain conditions, the outer phase of the protoplasmic membrane. Since proteins present in protoplasm are analogous to the fibrinogen functioning in the production of blood clot, since the fats are analogous to the oil employed in the emulsion systems, and the lipoids are substances possessed of physical and chemical characteristics in part those of proteins and in part those of fats," I believe that Clowes is entirely justified in considering that the physical structure of the protoplasmic film which regulates

the intake of foodstuffs and the output of waste products is analogous to that of the reversible diphasic systems, namely, emulsion types.

Summary.

1. It has been found that mixtures like $FeCl_3 + KCl$, $Al(NO_3)_3 + K_2SO_4$, etc., show considerable antagonistic action in the coagulation of positively charged ferric hydroxide sol. The same behaviour is found with the pair $K_4Fe(CN)_6 + KCl$ on arsenious sulphide sol. The conclusion has been drawn that by choosing suitable salt pairs, this antagonistic action can be shown in the case of practically all colloids.

2. It has been found that the antagonistic effect of mixtures of electrolytes on arsenious sulphide suspension is more pronounced with diluted sols than with the concentrated sols. This supports the view that the abnormal behaviour of this sol on dilution towards some univalent precipitating ions, is due to the greater stabilising action of the same-charged ion in diluted sols.

3. It has been shown that NaCl antagonises $CaCl_2$ in the coagulation of arsenious sulphide sol. At certain concentrations, the ratio of this antagonistic action is 100 molecules NaCl to one or two of $CaCl_2$. The analogy with biological cases is therefore very close.

4. To explain the general case of antagonistic action of electrolytes in various diphasic systems, the following principle has been deduced: If any ion having the same charge as the colloid particles themselves possess is adsorbed more, or is concentrated in excess in the interface between two phases at least at some concentrations of the electrolyte, it will tend to increase the charge and the dispersion of the suspension, and will antagonise the effect of the oppositely charged coagulating ion already present in or added to the system.

5. The contention of Clowes that the protoplasmic structure approximates to the type of reversible emulsion systems seems to be justified from a consideration of the physical factors operating in the growth and activity of the cell life.

ON THE TEMPERATURE RADIATION OF GASES

BY

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The object of the present paper is to present certain kinematical considerations regarding the problem of emission and absorption of light by gases. We are not yet in possession of the laws of thermal emission by gases, though a preliminary attempt has been made elsewhere. The kinematical results are not all new, but they are brought together here in a systematic manner, with a discussion as to how they can be employed in the practical and theoretical investigation of the problem.

To fix our ideas, let us start with a quantity of sodium-gas confined within a steel tube, within which the temperature and pressure (concentration) can be varied at will. The ends of the steel tube are provided with windows of some transparent material like quartz, so that both emission and absorption can be fully studied.

The processes which succeed each other as the temperature is raised have been described in detail elsewhere. At the lowest temperature, the gas does not emit any light, and when traversed by a beam of white light, absorbs only lines of the principal series 1s-2p. This phenomena has been qualitatively studied by Wood and Bevan. In this state, the vibrating electron in all the atoms is in the lowest quantum orbit 1s, having the energy $A-h$ (1s). But if we continue to heat up the mass, the vibrating electron will be displaced to the higher

quantum-orbits, 2p, mp, 2s, ms.........., and radiation will follow as a result of mutual interchange of orbits. First of all, we shall have the emission of 1s-2p line or lines (D_1 and D_2 in the case of Na) to be followed by the emission of 1s-mp series. When the mass of gas emits the line 1s-2p rather strongly, it can absorb lines of the sharp or diffuse series.

As a matter of fact, the 2p-ms lines (sharp and diffuse) could not be obtained as reversal lines in the laboratory under the usual conditions (J. J. Thomson, Phil. Mag., April, 1919). But a short time ago, Narayan and Messrs. Sur and Ghosh have obtained reversal of the subordinate lines of sodium and potassium by heating the gaseous mass to $800^\circ-900^\circ$C. Prof. King investigated the problem in his tube furnace, and confirmed the views quoted above in a striking manner.

But these studies are only of a pioneering nature. The problem before us is to obtain the intensity of emission for the individual series lines, as well as the power of absorption, as functions of temperature and concentration. For example, let I_{D_1} be the intensity of emission of D_1-light, α_{D_1} the coefficient of absorption of the vapour for the same light. We have to express I_{D_1}, α_{D_1} as functions of T and c (=concentration) and to verify the frequently expressed opinion that $\frac{I_{D_1}}{\alpha_{D_1}}=K$, intensity of emission of the black-body for the same wave-length at the same temperature. In treatments of such cases, we are invariably led on to the process of emission by black bodies. But there is an important distinction. Black-body emission, as usually treated, is a *surface phenomena*, while gaseous emission is a *volume effect*. The intensity of emission, say of D_1-light, will depend upon the number of atoms contained in the volume treated. If, temperature remaining the same, the concentration be doubled, the intensity of D_1-light will be greatly enhanced, if not actually doubled. The intensity of emission, as appearing to an outside observer, will depend to a large extent on the thickness of the emitting mass. The exact relation is thus obtained. Let OP represent the emitting

column, P is a point just outside the column, Q is a point distant x^1 from P. Let E and α denote the emissivity and coefficient of absorption for unit volume. Then of the light Edx, emitted by a layer of thickness dx at Q, only a fraction $e^{-\alpha x}$ succeeds in getting through the vapour to P. Hence the total light which succeeds in getting to P is

$$-\int_t^0 E e^{-\alpha x} dx = \frac{E}{\alpha}\left(1-e^{-\alpha t}\right) \quad \ldots \quad \ldots (1)$$

$$\text{If } t=\infty, \text{ the intensity at } P=\frac{E}{\alpha}=B \quad \ldots \quad \ldots (2)$$

The results (1) and (2) were first given by Guye. (See Wood, Physical Optics, p. 560.)

Fraunhofer Absorption.—Let us suppose that the radiant gas has a background of white light. Let the emissivity of the background for the wave-length treated be denoted by K. Then the intensity of light at P will be

$$Ke^{-\alpha t}+\frac{E}{\alpha}\left(1-e^{-\alpha t}\right)$$

The intensity of light arriving at P is made up of what remains of the continuous light after absorption plus the light emitted by the gaseous layer. Its *defect* from the intensity K of the uncovered white background is

$$K\left(1-e^{-\alpha t}\right)\left(1-\frac{E}{\alpha K}\right)$$

For reasons which it is quite easy to see, the fraction*

$$F=\left(1-e^{-\alpha t}\right)\left(1-\frac{E}{\alpha K}\right) \quad \ldots \quad \ldots (3)$$

may be called "Fraunhofer absorption coefficient" with

$$t=\infty, F=\left(I-\frac{E}{\alpha K}\right) \quad \ldots \quad \ldots \quad \ldots (4)$$

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* Schuster: Radiation through a Foggy Atmosphere. Astro. Journ., p. 1, 1905; Kayser: Astro. Journ., 14, p. 313, 1901.

Probable lines of application—Reversal experiments.—In the reversal experiments of Wood, Bevan, and Füchtbauer,[3] the temperature of the alkali vapour is so low, that $E=0$, $F=1-e^{-\alpha t}$ so that if the experiments were carried out for different thicknesses, then from accurate measurements of the spectrograms, (say with the aid of Koch's microphotometer), α could be deduced for the lines of the principal series of the alkali elements. But the experiments of Wood and Bevan being purely qualitative, nothing of the kind was attempted.

It can be easily perceived formulæ (1), (2), (3), (4) have a wide range of application. First of all, (2) may be used for finding out $\frac{E}{\alpha}$ and comparing it with black-body emission, secondly, (2) will give us E and α separately. For this purpose, we have to study the emission from the gas within the cylindrical tube mentioned previously over different ranges of temperature and pressure. Then the length of the tube is to be varied. We can thus obtain experimentally E and α as function of T and C. The process may be repeated in the case of a number of leading lines of the different series. This will put us in possession of the desired laws of absorption and emission.

Saturated absorption.—When t is sufficiently large, the emission$=\frac{E}{\alpha}$, *i.e.,* adding a fresh thickness of radiant matter will produce no change in the intensity of the emitted light. Such cases have been studied by Guye and Wood. In case of Fraunhofer absorption

$$F=\left(1-\frac{E}{\alpha K}\right)$$

the strength of the absorption line will be unaffected by the addition of a fresh layer of absorbing material. In such cases, absorption may be said to have reached saturation. Just what thickness of matter will suffice for the absorption to become saturated will depend on the series position of the line in question. For the fundamental lines 1s-2p, α is very large, so a

small thickness of matter will produce "saturated absorption." But for the higher members of the 1s-mp series, α rapidly diminishes and very large thickness of radiant matter may be required to produce saturated absorption. In the case of lines of the subordinate-series, $\alpha=0$ at low temperatures, and even miles of vapour will produce no appreciable absorption. With increasing temperature, α will be appreciable, but even then, a very large volume of t may be required to produce "saturated absorption."

Spectra of the Sun and the Stars.—

The foregoing ideas admit of immediate application to the elucidation of the spectra of the sun and the stars. What are called Fraunhofer-lines are not regions of absolute darkness, but they are the result of contrast between the intensity of the surrounding spectral region (which pass through the reversing layer unabsorbed), and the intensity of the Fraunhofer-line (which is made up of what remains of the photospheric light after absorption plus the emission of the gaseous mantle itself). On the hypothesis, that the emission from the central body is continuous, not necessarily identical with absorbing black-body emission and the gaseous mantle is a layer of thickness t,

$$F=\left(I-e^{-\alpha t}\right)\left(I-\frac{E}{\alpha K}\right).$$

But the assumption of a uniform density in the stellar atmosphere will scarcely commend itself to the astrophysicist. Let us make the next best assumption that the distribution of mass in the gaseous mantle follows the exponential law $e^{-\beta z}$ and consequently the number of emission and absorption centres decrease according to the same law. The second part of the assumption is not quite in accordance with facts, as we know that a reduction in concentration is always attended with an enhancement of the stimulus. But it is the best we can make under the present state of knowledge. Lastly

the temperature of the gaseous layer also is supposed to be uniform. Now if K be the intensity of the photospheric light, its intensity after traversing the absorbing layer can be shown to be given by

$$K\,e^{-\frac{\alpha}{\beta}\left(I-e^{-\beta t}\right)} \quad \ldots \quad \ldots \quad \ldots (5)$$

If E = intensity of gaseous emission at the bottom of the gaseous mantle, the intensity of transmitted light is given by

$$\frac{E}{\alpha}\left[I-e^{-\frac{\alpha}{\beta}(I-e^{-\beta t})}\right] \quad \ldots \quad \ldots (6)$$

Hence the Fraunhofer-absorption factor is given by the expression

$$F=\left[I-e^{-\frac{\alpha}{\beta}\left(I-e^{-\beta t}\right)}\right]\left[I-\frac{E}{\alpha K}\right] \quad (7)$$

Comparing this formula with (3)

$$F=\left(I-e^{-\alpha t}\right)\left(I-\frac{E}{\alpha K}\right) \quad \ldots \quad \ldots (3)$$

we find that $\left(I-\frac{E}{\alpha K}\right)$ is common to both. When β is small (7) reduces to (3). But if β o, $t=\infty$, we have

$$F=\left[I-e^{-\frac{\alpha}{\beta}}\right]\left[I-\frac{E}{\alpha K}\right] \quad \ldots (7A)$$

Intensity of Fraunhofer-lines.—A word or two may be necessary concerning the intensity of Fraunhofer-lines as ordinarily defined, and the intensity as implied in the foregoing formulæ. Ordinary methods of labelling the intensity of Fraunhofer-lines are very arbitrary, and ought to be discarded in favour of some rational system. Suppose we obtain the spectrogram of the solar spectrum. Then the intensity of the various regions may be determined with the aid of Koch's[1] microspectrophotometer. The smoothed curve will represent the emission-curve for different wave-lengths of the central

[1] Schwarzschild. Berl. Ber., 1914, carries out similar measurement for the H—K lines of the solar spectrum.

photosphere, the hollows will correspond to the various Fraunhofer-lines. The greater the depth of a hollow, the more intense is the Fraunhofer-line. If 'h' be the height of the smoothed curve (at the wave-length considered), be the height of the hollow above the null-line, $\frac{h-h^1}{h}$ represents "Fraunhofer-absorption F" as defined in (3) or (6). For broad lines or lines of irregular construction, an averaging over the area of the line may be found more advisable.

If the system be adopted, the intensity of a strong line like the H or the K may be found to be say ·95, while a faint line 00 on Rowland's scale may be ·05. The method proposed will enable us to estimate the value of

$$F = \left[I - e^{-\frac{\alpha}{\beta}}\left(I - e^{-\beta t}\right)\right]\left[I - \frac{E}{\alpha K}\right]$$

and provided the first factor can be neglected to obtain an idea of the value of $\frac{E}{\alpha K}$ for different lines of the same element.

Vanishing of Fraunhofer-absorption.—As is shown by formula, Fraunhofer-absorption may vanish from two causes, either

$$\text{when } I - e^{-\frac{\alpha}{\beta}}\left(I - e^{-\beta t}\right) = 0 \quad \ldots \quad \ldots \text{(A)}$$

$$\text{or} \quad I - \frac{E}{\alpha K} = 0 \quad \ldots \quad \ldots \text{(B)}$$

Since β is always finite, the condition (A) can arise only when $\alpha = 0$, *i.e.*, the gaseous mantle contains no atoms capable of absorbing the wave-length in question. This does not make the second factor indeterminate, since absorptive power always precedes emissive power

when $\alpha = 0$, $E = 0$, and $\frac{E}{\alpha}$ is presumably 0.

But Fraunhofer-absorption can vanish even when $\frac{E}{\alpha} =$ K, *i.e.*, emission by the infinite gaseous layer equals the emission by the back-ground.

Fraunhofer-absorption negative. Phenomena of bright lines.—

If $\frac{E}{\alpha} > K$, F is negative, the gaseous omission is stronger than the emission from the back-ground. In such a case, the line will appear bright on the continuous back-ground.

Possibility of $\frac{E}{\alpha}$ being > K.—We are thus again brought to the old question if $\frac{E}{\alpha}$ can ever equal or become greater than K, the intensity of black-body emission. Gibson[4] performed an experiment on reversal of the green thallium line from which he concluded that $\frac{E}{\alpha} = K$. But it has been shown elsewhere that his conclusion was based upon an erroneous interpretation of his experimental results. The subject is discussed at some detail in Wood's Physical Optics, second edition, pp. 593—597. Wood[5] cites an experiment by Paschen who compared the light of the two D-lines in the sodium flame with the total intensity of a region completely enclosing the D-lines, in the continuous spectrum of a black substance heated in the same flame. The total intensity of the D-radiation was more than twice as great as that of the region of the continuous spectrum which enclosed them.

If we regard that emission by the flame is a purely thermal process (an assumption which will be denied by many physicists), then the above experiment proves that $\frac{E}{\alpha}$ may not only equal, but can be greater than K.

There is evidence from stellar spectra that with rising temperature, $\frac{E}{\alpha}$ in the chromospheres of stars increases very rapidly. For example, Evershed[6] records :

"Again, while the majority of solar lines are intensely dark, showing in fact no photographic action at all, the Sirius

lines for the most part are not black but grey, the intensity within them being perhaps one-third or one-half of that of the continuous spectrum." This implies that for the sun, $\frac{E}{\alpha}$, for H and K at the chromospheric temperature (5,000°K), is small compared with the black-body emission at the photospheric temperature (6,000°K) for all the lines treated by Evershed. But in Sirius if we take the photospheric temperature to be 10,000°K, that of the chromosphere to be $10{,}000/\sqrt[4]{2} =$ 8,300°K, $\frac{E}{\alpha}$ at 8,300°K is half or one-third of K at 10,000°K for the lines treated by Evershed. Thus $\frac{E}{\alpha}$ seems to rise much more rapidly with temperature than K.

It is interesting to note that in the Sirius spectrum, the Mg-line 4481 is an exception to the above rule. Evershed says that it is nearly black. This means that $\frac{E}{\alpha}$ for Mg^+ 4481 is negligible compared to K. This is in accordance with the view that enhanced lines require a much higher temperature for their development, and that for this class of lines at least $\frac{E}{\alpha}$ is decidedly not equal to K at the same temperature.

It is quite possible that with increasing temperature at the chromospheric temperature may be larger than K at the higher photospheric temperature. In such a case, we shall have a bright line superposed on a continuous spectrum.

This is only thrown as a suggestion to account for the occurrence of bright lines, and presupposes that a temperature equilibrium has set in between the photosphere and the chromosphere of the star. The assumption is certainly not true of the Novæ and certain stars with peculiar spectra.

In the foregoing discussion, I have not taken account of the phenomena of scattering which has been treated in a masterly manner by E. A. Milne,[7] nor of the opacity produced

by free etectrons in the solar chromosphere. The last subject has been treated very fully by J. Q. Stewart.[8] But scattering and absorption of radiation by free electrons will modify only the continuous spectrum, while the object of this paper has been to treat the Fraunhofer-absorptions more systematically.

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ON THE CHOICE OF STRIKING POINT IN THE PIANOFORTE STRING.

BY

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In a series of papers[1] it has been shown that the elasticity of the hammer felt must be taken into consideration to calculate the duration of impact. It is this quantity which controls the quality of the note. The amplitude of partials, their duration, etc., depend upon this. The variation of the tone quality also depends upon the power of changing the duration of impact by 'touch.' In this paper a preliminary account is given of the experimental investigation on the amplitudes of the partials from a steel string struck at different points, and a comparison has also been made with the theory as given in Phil. Mag., vol. 49, page 121 (1925), the result of which is to indicate that the choice of the striking point should be such as to make the ratio of the free period of vibration of the string to the duration of impact equal to 2. Very recently some work[2] has been done in this direction by others.

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[1] Phil. Mag., vol. 47, p. 1142 (1924); vol. 49, p. 121 (1925). Ind. Assn. Proceedgs., vol. 10, part I (Calcutta).

[2] Phil. Mag., vol. 50, p. 491 (1925). Proceedgs., Ind. Assn., vol. 8, part II.

EXPERIMENTAL METHODS.

A piano-string was fixed over two bridges on a sonometer and kept vertical by suitable supports. The string was struck by a pianoforte hammer and key which were taken out from an actual pianoforte. The system used was a tape check action. The variation of the striking point was made by raising or lowering the sonometer. It was always carefully arranged that the hammer had full play, for if the hammer was very close to the string the note was dull. The point struck was photographed by a falling plate; in some cases the trace of an electrically maintained tuning fork was simultaneously photographed to obtain the duration of contact. In order to strike the key always with the same force or to give the hammer the same velocity a very simple arrangement was made.

To a wooden axle a wheel of the shape shown was fixed just over the key; it was arranged that a kilogram load should always fall through a height of 10 cm. and give one revolution to the wheel, which presses the key instantaneously, thus giving the hammer always the same velocity. The frequency of vibration of the string was found out from the plates in which the simultaneous record of the tuning fork was obtained. Having no mechanical analyser the curves were analysed by the schedule-method given by H. O. Taylor (Phys. Review, Oct. 1915). For this purpose the curves were magnified 50 times and a faithful trace was taken, then the ordinates were carefully measured. Below is given a table of the amplitudes of 5 components with different hammers at different points. For the sake of comparison the duration of contact is also given there.

TABLE 1.

Length of the string 100 cm. Freq. 88 per second.
Mass per unit length ·0961 gm. per cm.
Velocity of impact 2×10^4 cm. per sec.

No.	a	$\frac{T}{\phi}$	Hammer No.	1	2	3	4	5	REMARKS.
1	8	2·3	1	1·33	1·09	·078	·122	·21	
2	11	1·85	1	3·16	2·75	·96	1·06	·031	
3	12·5	1·80	1	2·9	2·6	·90	·91	·24	
4	14	1·56	1	1·8	1·3	·78	·71	·25	
5	16·5	1·44	1	3·07	1·7	·62	·31	·20	
6	20·5	1·1	1	3·66	1·34	·50	·27	·09	
7	12	1·08	3	2·08	1·05	·78	·297	·08	
8	15·2	·97	3	3·4	1·2	1·71	·144	·37	
9	17	·91	3	5·1	1·82	·84	·13	0	
10	20	·83	3	5·7	1·08	1·36	·31	0	
11	11·3	2·9	5	·404	1·12	1·15	·25	·13	
12	15·7	2·4	5	1·98	1·48	·47	·29	·30	
13	19	2·1	5	3·29	2·06	·72	·17	·086	

a = Striking distance from nearer bridge.

$\frac{T}{\phi}$ = Free period of vibration of string / duration of impact.

Effective mass of hammer No. I = 7·1 gm. $\frac{T}{\mu} = 1·3$

No. III = 19·0 " $\frac{T}{\mu} = ·56$

No. V = 2·6 " $\frac{T}{\mu} = 0$

TABLE 2.

$l = 100$, Freq. 124, $\rho = ·0211$. Velocities of impact arbitrary.

No.	a	$\frac{T}{\phi}$	1	2	3	4	5	6	7	8	9	Hammer No.
1	1/6		1	·24	·111	·072	·047	·03	·033	·368	·354	5
2	1/7		1	·23	·118	·022	·048	·02	·015	·135	·020	"
3	1/8		1	·51	·293	·091	·094	·07	·016	·018	·031	"
4	1/9		1	·34	·098	·095	·041	·106	·032	·034	·010	"
5	1/6		1	·184	·244	·048	·014	·037	·038	·007	·021	7
6	1/7		1	·012	·181	·068	·042	·043	·008	·008	·003	"
7	1/8		1	·092	·012	·04	·007	·023	·021	·018	·18	"
8	1/9		1	·147	·092	·108	059	·042	·188	·015	·009	"

TABLE 3.

$l = 100$, Freq. 84, $\rho = \cdot 0792$

No.	a	$\frac{T}{\phi}$	1	2	3	4	5	6	7	8	9	Hammer No.
1	1/6	1·55	1	·407	·185	·103	·081	·018	·010	·032	·049	7
2	1/7	1·67	1	·31	·164	·10	·050	·20	·013	·023	·059	,,
3	1/8	1·86	1	·69	·083	·171	·052	·043	·017	·017	·141	,,
4	1/9	1·97	1	1·03	·285	·19	·118	·162	·054	·033	·128	,,
5	1/6	2·48	1	·981	·323	·103	·051	·074	·062	·069	·042	5
6	1/7	2·74	1	·756	·661	·253	·114	·031	·080	·023	·068	,,
7	1/8	2·95	1	1·81	1·2	·63	·25	·111	·146	·035	·064	,,
8	1/9	3·1	1	1·84	1·03	·53	·32	·28	·095	·054	·094	,,

$$\frac{T}{\mu} = \cdot 11 \text{ for } H_1$$

Discussion of Results.—The simple formula for the amplitude of any component has been given in Phys. Review, vol. 24, p. 456 (1924).

For the same string and the same velocity of impact the amplitude of the sth component at the point struck is given by

$$A_s = \frac{\sin^2 s\pi a/l.\ \cos (s\pi\phi/T)^*}{s(s^2 - \frac{1}{4}T^2/\phi^2)} \quad \ldots \quad \ldots \quad (1)$$

discarding quantities which are small.

Below is given a table of the amplitudes of the fundamental and the octave for different values of $\frac{T}{\phi}$ for the same value of $\sin\frac{s\pi a}{l}$ calculated from (1).

* Recently the author has been able to make further approximations in the formula.

TABLE 4.

No.	$\frac{T}{\phi}$	1	2	3	REMARKS.
1	·5	1·06	·125		
2	·7	·3	·12		
3	1·0	1·33	·133	·04	Fundamental maximum
4	1·5	·43	·08		
5	1·7	1·0	·13		
6	2·0	1·0	·17		Fundamental maximum
7	2·5	·55	·2		
8	3	·4	·14	·049	

From Table 1 we find that the fundamental is maximum at $\frac{T}{\phi}=1$ and $\frac{T}{\phi}=2$ which are theoretically required when

$$\sin \frac{s\pi a}{}$$

remains the same. In the experiments that have been tabulated the ratio $\frac{T}{\phi}$ was changed, firstly by changing the striking distance and secondly by changing the hammer.

$$\frac{T}{\phi}=\frac{1}{\pi N}\left(\frac{T}{M}\right)^{\frac{1}{2}}\left\{\frac{1}{a\left(1+\frac{T}{\mu a}\right)}-\frac{\rho}{4M}\right\}^{\frac{1}{2}} \quad \ldots \quad (2)$$

M = effective mass of hammer.

N = frequency.

A correct comparsion of Table 4 with Tables 1, 2 and 3 can only be made when the amplitudes tabulated there are divided by

$$As=\frac{As \text{ obs}}{\sin^2 \frac{s\pi a}{l}} \quad \ldots \quad \ldots \quad (3)$$

The presence of the factor $\sin \frac{s\pi a}{l}$ is to increase the amplitude as we move away from the bridge. If the variation of the amplitude due to change of $\frac{T}{\phi}$ with change of a

is much larger than the increase of sin $\frac{s\pi a}{l}$ the rise and fall of amplitude will still be found. And this is the case in hammers Nos. 1 and 5, while in the case of hammer No. 3 the amplitudes go on increasing with increase of $\sin^2 \frac{s\pi a}{l}$. This, as just now pointed, is due to the fact that the percentage variation of the amplitude due to change in $\frac{T}{\phi}$ is smaller than that of the increase due to $\sin^2 \frac{s\pi a}{l}$. In other words, the effect is masked. At 20 cm. from the bridge in the case of H. 5, $\frac{T}{\phi}=2{\cdot}1$, while in the case of H. 1 $\frac{T}{\phi}=1.$; so that the sin $\frac{s\pi a}{l}$ remains the same in both the cases and the amplitudes of the fundamental and the octave are related as

TABLE 5.

3 : 1 : 5/30 for H.1.
3 : 2 : 7/30 for H.5.

Hence we find that though the maximum of the fundamental is almost the same in the case when $\frac{T}{\phi}=1$ or when $\frac{T}{\phi}=2$, the octave and the third component increase in amplitude when $\frac{T}{\phi}=2$. Lastly, reducing the amplitudes to the same scale we obtain

TABLE 6.

	H.1	H.3	
1	11	14	$\frac{T}{\phi}=1.$
2	4	7·5	
3	1·4	5·0	

According to the simple theory the amplitudes calculated in Table 4 should be equal, but there are other factors, namely, the stiffness of the string, the reflections which influence the amplitudes to a large extent and which we have not taken into consideration. From Table 4 we also find that the amplitude of the fundamental is again maximum when

$\frac{T}{\phi}=\frac{1}{2}$. This was not experimentally verified, but the ratio $\frac{T}{\phi}=\frac{1}{2}$ does not seem to be of practical use, for then the reflections from the farther end in presence of the hammer on the string would render the partials non-harmonic. Discarding this case we must have the ratio $\frac{T}{\phi}=1$ or 2 to have a large fundamental.

[*Choice of the Striking Point.*—From Table 5 we find that the amplitude of the octave and the third component in the case $\frac{T}{\phi}=2$ is greater than in the case $\frac{T}{\phi}=1$. The presence of the third component is theoretically explained by the second term in equation 16 (Phil. Mag., vol. 49, page 128, 1925). Further in this case the impact ceases before the wave reaches the other end. From these considerations it seems, therefore, that the choice of the striking point is made by making the ratio $\frac{T}{\phi}=2$. This had been verified in the case of the piano which I possess. The ratio $\frac{T}{\phi}$ was calculated from formula (2).

$l=91{\cdot}5$ cm., $\rho={\cdot}137$ gm. per cm.

Tension $3{\cdot}26\times10^{8}$ dynes.

Freq. 275 approx.

Maxima at 11·1 cm.

Mass of hammer 10·5 cm.

$\frac{T}{\phi}=1{\cdot}9.$

Hence we see that the choice of the striking point depends upon the ratio $\frac{T}{\phi}$ which must be 2 : 1.

Now $\phi=\frac{\tau}{2}$ is fixed and it can be achieved in two ways, *viz.*, by changing the mass of the hammer or the striking distance, so that their product remains constant. Now α the striking distance should not be greater than a finite value, otherwise the waves undergo modifications from reflections from

the farther end and the components would be rendered non-harmonic for reasons mentioned before. Also a should not be very small, for on account of the factor $\sin \frac{s\pi a}{l}$ the amplitude of the resulting vibrations would be very small. Hence a must lie somewhere between $\frac{1}{9}$ to $\frac{1}{7}$ l. When a is fixed the mass of the hammer is determinate. For the best musical note the partials must converge in a particular way. For a given value of $\frac{T}{\phi}$ the convergence of the partials is the same when $\sin\frac{s\pi a}{l}$ is constant. But on account of the latter factor the convergence is different at different points, even if $\frac{T}{\phi}$ is made the same at different points of the string by arranging so that the product of the mass of the hammer and the striking distance remains the same. The value of a for the best musical effect therefore also depends upon the factor $\sin \frac{s\pi a}{l}$. This point is under investigation with the help of a piano-tuner.

Coming back to the comparison of Tables 3 and 4 we find that the ratio of the amplitudes of the fundamental and the octave is the same for a given value of $\frac{T}{\phi}$ as indicated in Table 4, *i.e.*, when $\frac{T}{\phi} = 1{\cdot}55$, the theoretical value of the ratio is ·44, and experimentally it is found to be ·41. Again when $\frac{T}{\phi} = 2$, the ratio is 1·17 and experimentally it is 1·03; when $\frac{T}{\phi} = 1{\cdot}7$, the ratios are ·6 and ·3. Similarly the theoretical conclusions for other values of $\frac{T}{\phi}$ are approximately verified experimentally.

Sound Board.

The effect of varying the striking point on the string on the amplitude of vibration on the sound board was also investigated. For this purpose a piano whose front part was taken

away was used. The velocity of impact was kept constant by the key and wheel arrangement described before. For photographing the vibrations of the sound board, a steel strip S was soldered to a thick piece B perpendicularly and the piece was screwed to the sound board. The strip pressed against a rolling needle N supported on a screw top which could be raised or lowered at pleasure. This was firmly kept in position by another nut R. To the rolling needle a small concave mirror was attached, and a spot of light from an arc lamp was focussed on the moving photographic plate. One very striking phenomenon is the rise and fall of the amplitude of vibration. In some cases the amplitudes swell out first and then diminish steadily. At other points the amplitude passes through small rise and fall and then attains the maximum value, after which there is a steady fall. When the striking distance is small, the rise and fall do not appear to be marked, but at greater distances the number of rise and fall and the variation are very marked, as can be observed from the pictures (the photographic plate was dragged at approximately the same velocity). A fuller account with the theory of the vibrations of sound board will be presented shortly.

Measurements were taken of the biggest amplitude at different points and the average values are tabulated below:

TABLE 7.

No.	$\frac{a}{l}$	Amplitude.	Reduced amplitude.
1	1/10	1·4	4·5
2	1/8·3	1·75	4·9
3	1/7·3	1·4	3·4
4	1/6·3	1·9	3·8
5	1/5·5	1·4	2·6
6	1/5·3	2·0	3·6
7	1/4·6	2·4	3·8
8	1/4	2·8	3·8

The amplitude at different points undergo a variation on account of the change in the value of $\sin \frac{s\pi a}{l}$, and hence they must be reduced to the same scale by dividing them with $\sin \frac{s\pi a}{l}$; column 3 was obtained in this way and we find that the amplitude is maximum at 1/8·3.

The vibration that results in the sound board is a forced vibration and it is expected that the maximum forced vibration would result when the force is maximum. Now we have seen that at $a = 11{\cdot}1$ the ratio for the same piano string and hammer system $\frac{T}{\phi}$ is 2. Hence the effect observed is simply due to the maximum force on the bridge due to the maximum vibration of the string. The sound board shown by Berry[1] has a minimum free vibration at this place.

Conclusion.

The experimental results of analysis of different vibration curves obtained by striking the string at different points with the same velocity are:

(1) Fundamental is maximum when $\frac{T}{\phi} = 1$.

(2) Fundamental is maximum when $\frac{T}{\phi} = 2$.

(3) The first and second harmonics are stronger in case 2 than in 1.

(4) Choice of the striking point in the piano is made in such a way so as to obtain $\frac{T}{\phi} = 2$.

(5) The sound board reproduces the maximum vibration of the string at $\frac{T}{\phi} = 2$.

(6) The choice of the striking point should be such that it lies between 1/9 to 1/7 of the length of the string.

The author begs to record his debt of gratitude to Prof. M. N. Saha for his kindly supplying him with a pianoforte.

[1] Phil. Mag., vol. 19, p. 647 (1910).

Plate No. 1

Fig.

1

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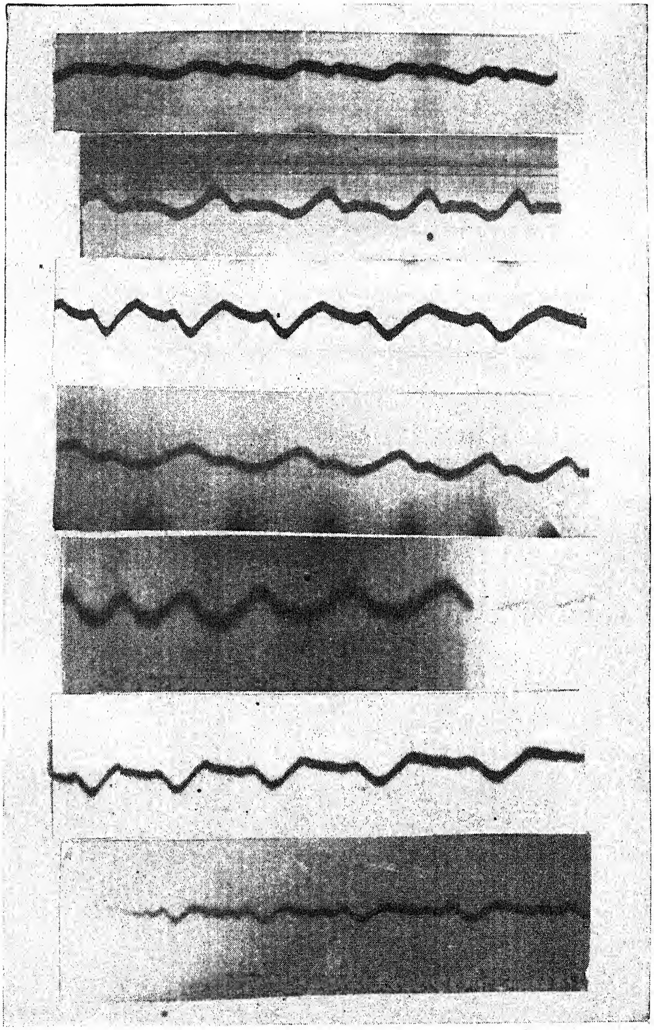

Note :—

Further extensions of Table 1 :—

$l=95$ cm., Freq. 130, $\rho=\cdot022$ gm. per cm.

$T=1\cdot34\times10^7$. $x=11$ cm. Const.

No.	$\frac{T}{\phi}$	1	2	3	REMARKS.
1	1·3	4·7	1·2	1·1	
2	·98	4·8	1·1	·32	
3	·52	1·27	1·48	·69	Different hammers.
4	·82	4·3	·69	·56	
5	1·1	4·9	1·0	·40	

$l=92$ cm. $T=1\cdot88\times10^7$. Freq.$=160$.

$\frac{T}{\mu}=0$. $M=2\cdot6$ gm. Const.

No.	a	$\frac{T}{\phi}$	Reduced amplitude. 1	2	3
1	6	1·9	23·5	6·2	·42
2	8	1·62	23·3	4·0	·93
3	11	1·36	18·1	1·4	·46
4	16	1·1	20·2	·6	·38
5	18·5	·95	15·0	1·1	1·07

$l=100$, Freq.$=88$, $\rho=\cdot096$, $a=20$ cm.

No.	$\frac{T}{\phi}$	Amplitude of the fundamental.	
0	·94	6·2	
1	1·0	9·2	
2	1·2	7·9	
3	1·29	7·7	
4	1·32	5·9	$x=$Const.
5	1·6	5·4	
6	1·8	7·9	
7	2·0	9·4	
8	2·3	3·0.	

It has been shown that the amplitude of the fundamental and the octave are maximum when $\frac{T}{\phi}=1$ or. 2 Now the question arises whether the maximum values of the amplitudes are different for different values of m/M and a/l, where m$=$mass of the string and M$=$mass of hammer ; and $a=$ striking distance, $l=$length of the string. The following table has been drawn up from experimental values:

Maximum Fundamental Velocity of Impact Constant.

No.	$T_0 \times 10^{-7}$	T/ϕ	a/l	$(m/M)^{\frac{1}{2}}$	Funda.	Octave.
1	2·97	1·1	1/5	·9	9·3	3·9
2	1·39	1·1	1/6	·8	20·2	1·6
3	1·88	1·1	1/8·6	·6	14·0	1·03
4	2·97	1·85	1/9·1	·8	6·3	1·4
5	2·97	2·1	1/5·2	1·6	5·7	2·2
6	1·88	1·9	1/16	·8	23·5	6·2

T_0 = tension.

By comparison it is found that the maximum value for the same velocity of impact and tension, is approximately the same for different values of m/M and a/l, but it changes with the change in tension. When the tension increases, the maximum value of the amplitude decreases. This is expected to be the case on general grounds. Now theoretically T/ϕ is given by :

$$\frac{T}{\phi} = \cdot 64 \left(\frac{m}{M} \right)^{\frac{1}{2}} \left[\frac{1}{a/l} \cdot \frac{1}{X}^{\frac{1}{2}} \right]$$

$$X = (1 + T_0/\mu a)$$

How the maximum amplitude depends upon tension requires further experimental investigation. It is evident from the above formula that whatever be the values of m/M or a/l, their product must be such as to ensure $\frac{T}{\phi} = 1$ or 2, and then the amplitude of the fundamental has the same maximum value.

Some vibration curves of the struck string are appended in Plate (1) and in Plate (2), ; their details are tabulated below :

Pl. (2)

No.	a	Length	Freq.	P
1	20	100	88	·096
2	16	95	130	·022
3	16·5	100	88	·096
4	19	95	130	·022
5	12·5	100	88	·096
6	19	95	130	·022

PLATE No. 2

FIG.

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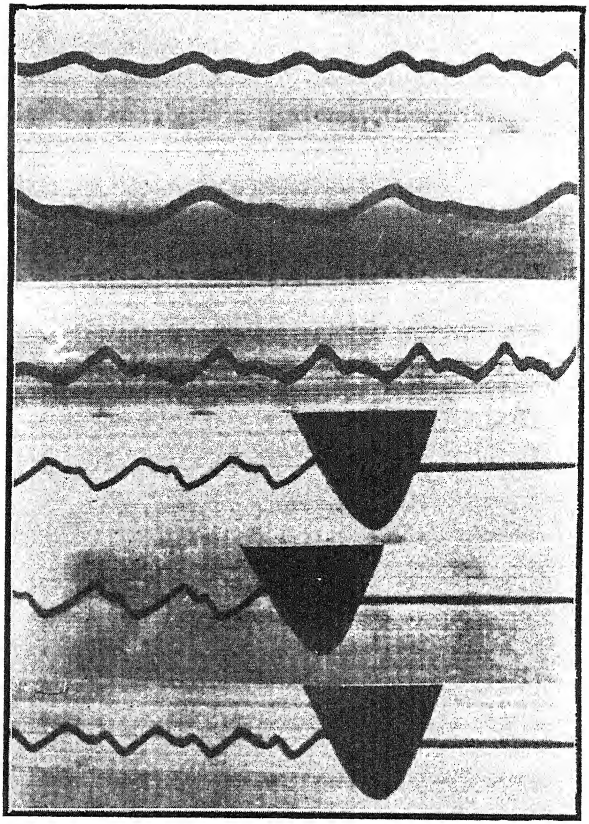

RAINBOWS

BY

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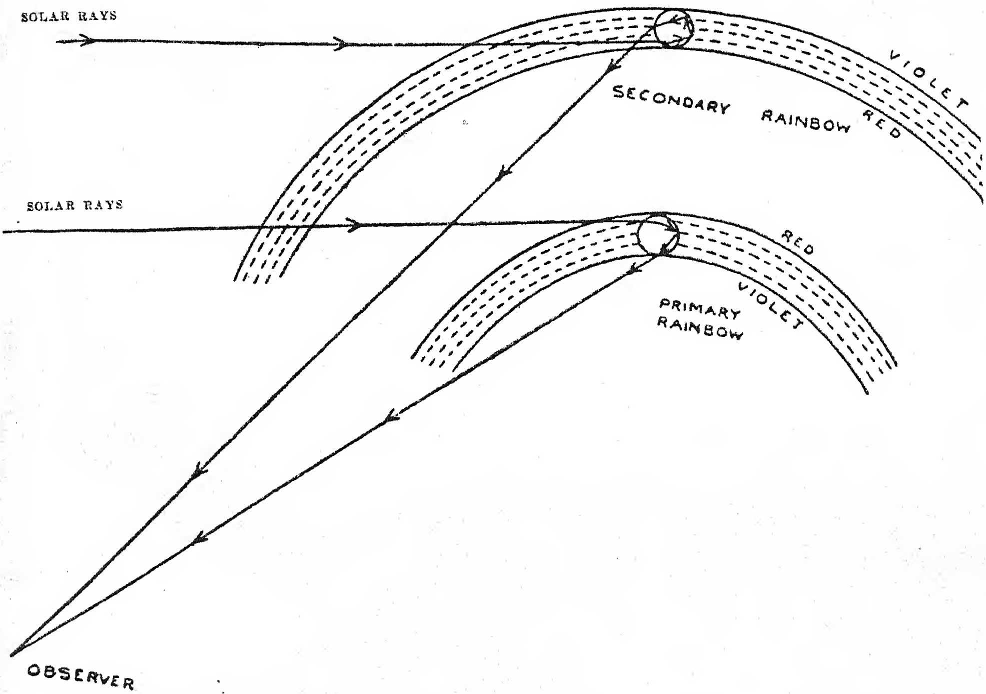

Fig. 1

Introduction.

The phenomenon of the beautiful tints in arc forms in sky commonly described as rainbows must have excited the curiosity of man from remotest antiquity and probably filled his mind with that awe and wonder with which he is inclined to observe Nature in her various aspects. In fact these colour phenomena have become so commonplace that it may be thought

at first sight to be altogether a waste of time and energy in writing an article upon them and contributing it to a serious journal. But it is this very commonplace character of these phenomena which demands our closest attention and scrutiny unless we allow ourselves to lose sight of any possible new developments in their objective or theoretical aspects. And such developments are sure to come out; because Nature knows no bounds and man's subtle power is so immense. Nor is it to be supposed that rainbows are a distinct and an isolated phenomenon. As will be indicated in what follows besides showing that white light is of composite character they are related to other meteorological factors in a very subtle way. Perhaps it would be no exaggeration to say that rainbow phenomena are second to none in point of importance in meteorological optics.

General Description of Rainbow Phenomena.

As the word implies rainbows are always associated with rain. They are usually seen in Nature when sun shines upon falling rain. A very beautiful display of hues is made when sun shines on the spray from a sea-wave. These are described as marine rainbows. Sometimes but very rarely coloured bows are also seen when rays from the moon fall upon raindrops. According to Aristotle who is supposed to be their first observer they occur only with full Moon. These are called lunar rainbows. Sometimes intersecting rainbows are seen. They are formed by parallel rays of light issuing from two sources, *e.g.*, sun and its image in a sheet of water located between the sun and the observer. The second bow is much fainter and its centre as much above the horizon as that of the other below it. Under favourable circumstances with falling rain and shining sun several bows of varying intensity and distribution of colours may be seen. The brightest of all of them is called the primary bow. Its radius subtends an angle of about 41° at the observer's eye and it exhibits brilliant spectrum colours intermingling with one

another. The outer edge is red and the inner edge violet while in between there are other colours. In addition to this there is often seen another bow of larger angular radius. This is called secondary bow. It is much fainter than the primary and its colour sequence is reversed. The space between the two bows is comparatively darker than the rest of the sky. In addition to these numerous other bows theoretically exist. The third and fourth (tertiary and quaternary) are situated between the sun and the observer who must face the sun if he cares to see them. The fifth (quinary) is situated in the same part of the sky as the primaty and the secondary and it is slightly above the latter. All these bows possess very small intensity and so generally escape notice. The common centre of the primary and secondary bows is as far below the observer as the sun above it and so usually less than a semicircle of these coloured arcs is visible. During the season when rainbows are seen the sun's elevation above the horizon is more than 41° the angular radius of the primary bows and consequently no bow is seen as then the centre goes far below the horizon. Sometimes due to superposition of different colours white rainbow is seen. This is described as "Ulloa's ring."

The colours of the bows are not always brought out to the same extent. The widths and brightness of successive bands also vary within wide limits. For example the rainbow of retreating thunderstorm is very sharply defined and shows brilliant colours, while that of a mist shows poor chromatic effect and is ill-defined. All these peculiarities have been now satisfactorily explained and it is seen that they depend upon size of raindrops.

Sometimes under exceptional circumstances bands essentially red or red and green or pink appear parallel to the primary and secondary bows. They are seen to lie within the primary and without the secondary. These are called supernumerary bows. They differ among themselves in purity, colour, width, etc., within very wide limits.

History of the theory of Rainbows.

Having thus summarised the rainbow phenomena it will be worth while to give historical development of their theoretical explanation. The rainbow phenomena appear to have attracted attention in remote antiquity both in Asia and in Europe. There are references in various accounts of the Deluge. In the Biblical narrative (Gen. IX, 12—17) the bow is taken as a sign of a covenant between God and man. Among Greeks and Romans there have been various speculations regarding the cause of the rainbows. Vitellio introduced the idea that the phenomenon was due to refraction of light. Later on in about 1311 Theodorich of Vriberg adopted the same idea. But his works were unknown till G. B. Venturi at Basel made them known. The same explanation was given by John Fleischer of Breslan and Fransciens Maurolycus about the end of the 16th century. In about 1611 Antonius de Dominus, Archbishop of Spalatro, showed by means of globes filled with water the formation of primary bow by two refractions and one internal reflexion and of the secondary by two refractions and two internal reflexions. Descartes in the year 1637 lent support to this theory by experiments and numerical investigations; but he could not explain the chromatic display. Sir Isaac Newton in 1704 explained the colours on varying refrangibility of light. The geometrical theory of Newton is treated in full in various elementary text-books of light. The basic facts upon which the whole explanation according to this theory is based are that (1) near the minimum value the deviation of rays of light alter very slowly with the angle of incidence and (2) this minimum value is different for different kinds of light for the same substance, *e.g.*, in the case of spherical drops of water for one interval reflexion the minimum deviation for violet (H line) is π—40°, 36′ and for Red (H L) it is π—42°, 22′. The rays as they emerge from the drop after one internal reflexion are closely packed about the direction of minimum deviation and

this is true for each of the colours separately and a dispersion is the result. The following figure as well as Fig. 1 will explain the formation of coloured arcs.

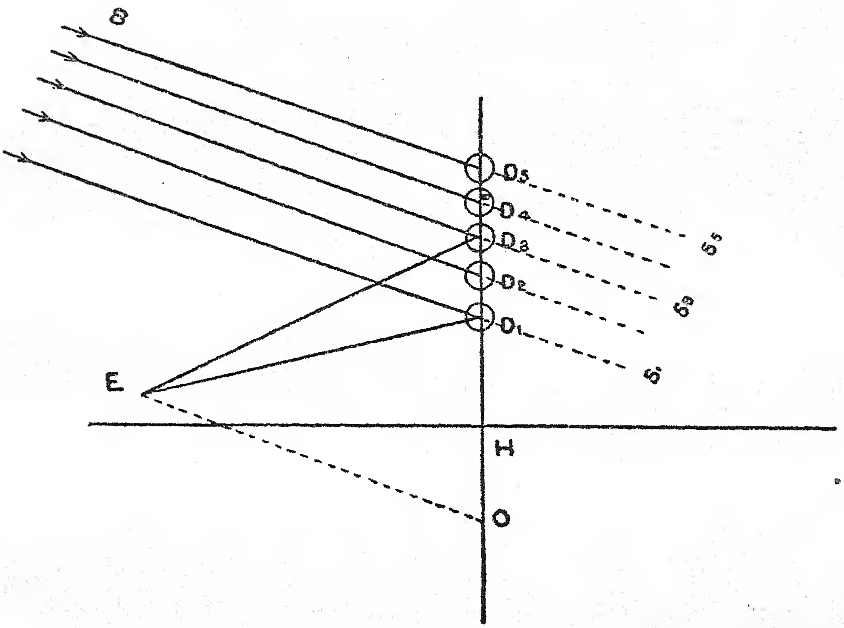

Fig. 2.

D, D_1 D_2, etc., drops of water. S system of parallel rays coming from sun. H, horizon. E, observer. O point of intersection of vertical with line EO parallel to sun's rays.

If $\angle S_1D_2E$ = angle of minimum deviation for one reflexion then drop D_1 will appear bright. Now obviously all the drops situated at the same angular elevation from E will appear bright simultaneously and thus a bow with angular radius equal to D_1EO will be seen. Now since $\angle S_1D_1E$ varies from colour to colour, the bow will be coloured red on the outside and violet on the inside. The angular width for the coloured band would be $42°, 22' - 40°. 36' = 1°,46'$. This explains the formation of primary bow.

Similarly if the drop D_3 is such that $\angle S_3D_3E$ is the minimum deviation angle for two internal reflexions, then this

together with other drops equally elevated from E will form secondary bow and it will be coloured for the same reason as that for the primary bow. And so on for other bows.

Such in brief is the geometrical theory of Descartes as developed by Newton. This theory however could not explain the formation of the supernumerary bows mentioned above.

In 1803-4 Thomas Young pointed out that the application of the principle of interference of light waves could explain the formation of supernumerary bows. A satisfactory theory of rainbows on the wave theory of light was developed by Sir George Airy in 1836—38 assuming the source of light to be point source.

Airy's theory was still further developed in certain details by Mascart and Lorenz. In 1898 Pernter minutely investigated the colours of rainbows. But the sun which is responsible for rainbow phenomena is certainly not a point source of light but has an apparent diameter of about 32′. And consequently theoretical results based on the assumption of a point source of light are sure to show certain discrepancies. This was realised by Pernter and so he wrote a note on a short calculation on the colours due to a source of finite dimensions by numerical addition of the results for the case of point source. A distinct theory for a source of finite dimension was later on developed by K. Aichi and T. Tanakdate of Tokyo (1904). This is then an extension of Airy's theory and this is where the theory of rainbow lies at present.

By geometrical drawing the alteration in the nature of a plane wavefront incident on a water drop as the wave enters and then emerges out can be studied. In Figs. 3a and 3b AB is the incident plane wavefront. Just after emergence from the drop it is transformed into the cusped wavefront ACB″ virtually originating from the

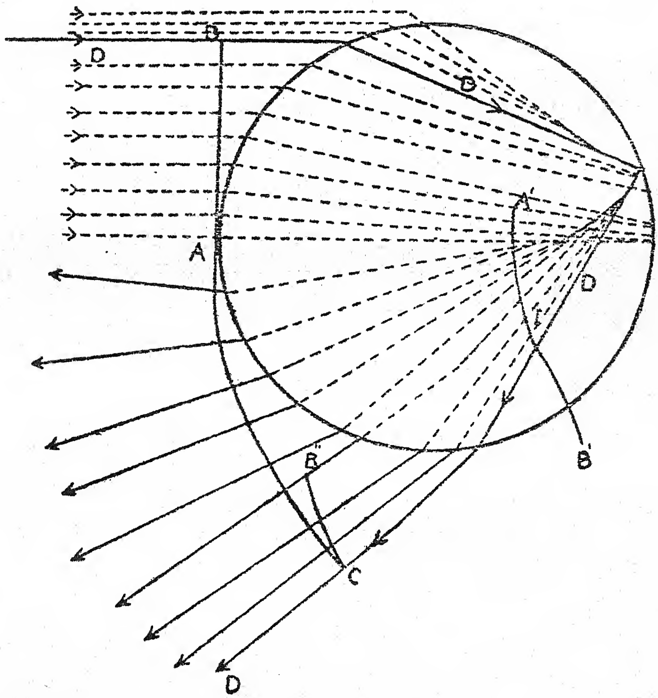

Fig. 3a.

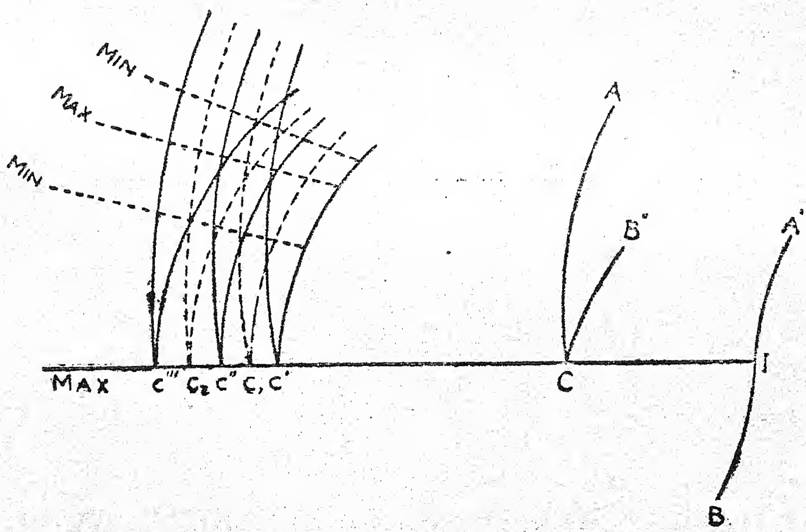

Fig. 3b.

inflexional wavefront A′IB′. DDD is the Descartes ray suffering minimum deviation for one internal reflexion. The cusped wavefront ACB″ travels forward parallel to itself away from the drop. At large distances from the drop the two portions of the cusped wavefront become arcs of circles and give rise to maxima and minima due to interference. When the source of light emits simultaneously radiations of different wavelengths, the maxima and minima of each are formed in different positions and polychromatic rainbows arise due to mixing of colours. Airy has obtained from theoretical considerations an equation to the inflexional wave to which the rainbow phenomena are due. The equation is

$$y = \frac{h}{3a^2} x^3 \qquad \ldots \qquad \ldots \qquad \ldots \quad (1)$$

where

$$h = \frac{(n^2+2n)^2}{(n+1)^2(\mu^2-1)} \sqrt{\frac{(n+1)^2-\mu^2}{\mu^2-1}} \qquad \ldots \quad (2)$$

n being number of internal reflexions, μ refractive index and a the radius of a drop

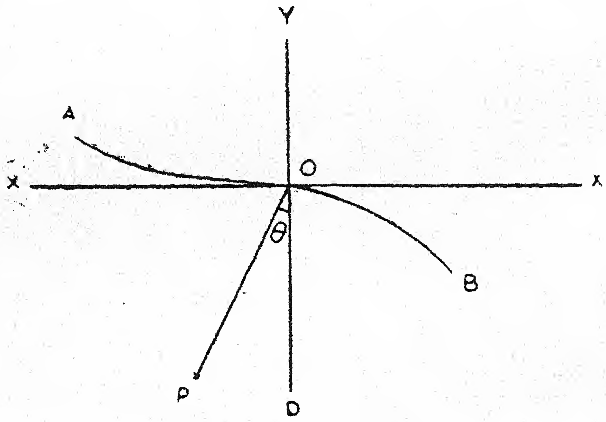

Fig. 4.

Let XX′, YD be the co-ordinate axes passing through the point of inflexion O of the inflexional wave AB. XX′ and

YD are respectively perpendicular and parallel to the direction of minimum deviation. Then the equation to the disturbance at a point in direction θ with YD is given by

$$S = k \int \operatorname{Sin} 2\pi \left[\frac{t}{T} - \left(\frac{hx^3}{3a^2} \operatorname{Cos} \theta - x \operatorname{Sin} \theta \right) \frac{1}{\lambda} \right] dx \quad \ldots \quad (3)$$

The amplitude of this disturbance for limits $\pm \infty$ is obtained after certain reduction to be

$$A = 2k \int_0^\infty \left(\frac{3a^2 \lambda}{4 \text{ h Cos } \theta} \right)^{\frac{1}{3}} \operatorname{Cos} \frac{\pi}{2} (u^2 - zu)\, du \quad (4)$$

This is the well-known Airy's rainbow integral. Here

$$\frac{zu}{2} = 2x \operatorname{Sin} \theta / \lambda \quad \ldots \quad (5)$$

$$\frac{u^3}{2} = 2h\, x^3 \operatorname{Cos} \theta / 3a^2 \lambda \quad \ldots \quad (6)$$

$$\text{and } \delta = \frac{\pi}{2} (u^3 - zu)\, du \quad \ldots \quad (7)$$

$$\text{Putting } \int_0^\infty \operatorname{Cos} \frac{\pi}{2} (u^3 - zu)\, du = f(z)$$

$$\text{Intensity } A^2 = 4k^2 \left(\frac{3a^2 \lambda}{4h \operatorname{Cos} \theta} \right)^{\frac{2}{3}} f^2(z) \quad \ldots \quad (8)$$

This shows that intensity depends upon $(\lambda a^2)^{\frac{2}{3}}$. But Mascart has shown in 1892 that it really depends upon $\left(\frac{a^7}{\lambda} \right)^{\frac{1}{3}}$

$$\text{thus } A^2 = \text{constant} \left(\frac{a^7}{h^2 \operatorname{Cos}^4 \theta\, \lambda} \right)^{\frac{1}{3}} f^2(k\theta) \quad \ldots \quad (9)$$

$$\text{where } k = 2 \left(\frac{6}{h} \right)^{\frac{1}{3}} \left(\frac{a}{\lambda} \right)^{\frac{2}{0}} \text{ from (5) and (6)}$$

Airy has evaluated $f^2(z)$ by an elaborate process. When the intensity is plotted against values of θ periodic changes in intensity are found as Fig. 5 shows.

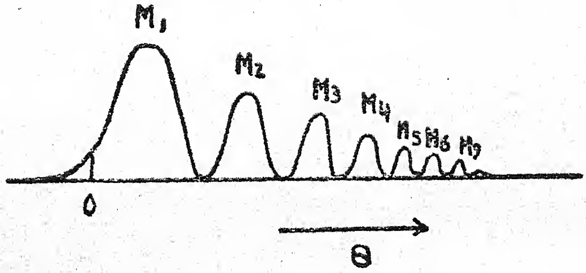

Fig. 5.

It is easily seen from this curve that the first maximum does not lie in the direction $\theta = O$ but a little beyond it. The first maximum corresponding to a principal bow has the largest intensity while the intensity of other maxima as well as their spacing decreases with increase in θ. The succeeding maxima of comparatively smaller intensity correspond to supernumerary bows which are of course coloured if the incident light is heterogeneous. According to Airy's investigations the angular positions of maxima and minima from the direction of Descartes ray are given by

$$\theta^{\frac{3}{2}} = (n+\tfrac{1}{4})\,\lambda\,\frac{9\,(4-\mu^2)^{\frac{1}{4}}}{8a\,(\mu^2-1)^{\frac{3}{4}}} \qquad \ldots \qquad (10)$$

$$\theta^{\frac{3}{2}} = (n+\tfrac{3}{4})\,\lambda\,\frac{9\,(4-\mu^2)^{\frac{1}{4}}}{8a\,(\mu^2-1)^{\frac{3}{4}}} \qquad \ldots \qquad (11)$$

respectively. The first maximum lies in the direction given by

$$\theta^{\frac{3}{2}} = \frac{9\lambda\,(4-\mu^2)^{\frac{1}{4}}}{32\,a\,(\mu^2-1)^{\frac{3}{4}}} \qquad \ldots \qquad \ldots \qquad (12)$$

and not in the direction of Descartes ray. This reduces the angular radius of the principal bow to some extent. In the same way it is shown that the radius of the secondary bow is slightly larger than that given to it by Geometrical theory. As the above equations show, the distances of the spurious bows from the principal ones vary with the diameter of rain-drop. That is why spurious bows are seen at comparatively higher levels where the drops are of comparatively smaller size.

Pernter has studied the distribution of colours in primary bows due to drops of various sizes. The following table brings out the close connection between size of drop and the colour of spurious bows.

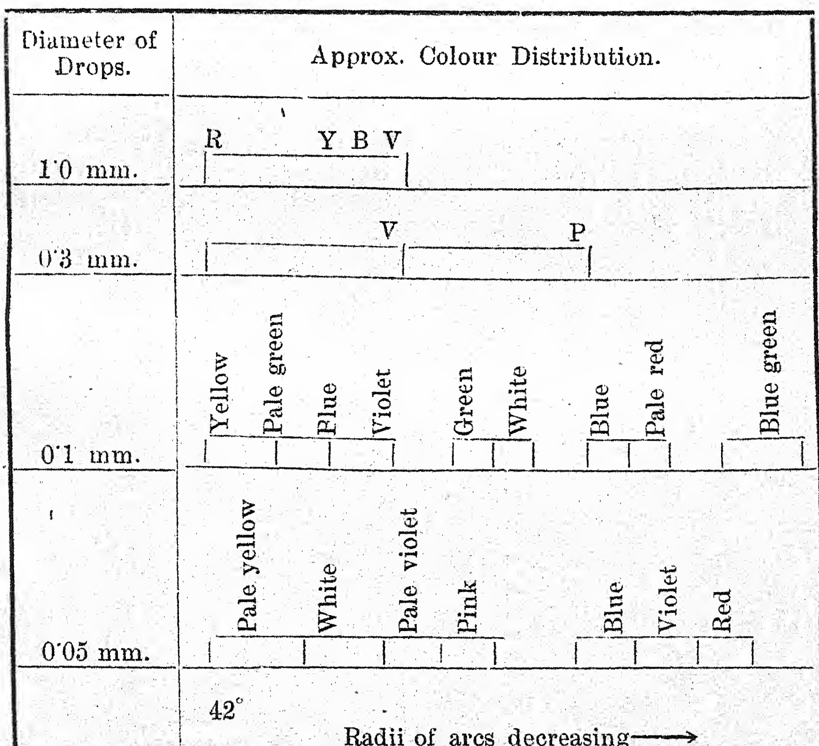

Fig. 6.

From the nature of the colours of supernumerary bows we can get some idea of the size of drops which preponderate. Thus when pink is seen, the preponderating drops have got diameters less than 0·1mm. With drops of larger diameter than 1 mm. rainbow of Descartes theory is obtained. Size of drops involve various meteorological factors and it cannot be gainsaid that close scrutiny of rainbows is worth the trouble, since it is bound to throw light on some important meteorological conditions. It will be beyond the scope of the present article to discuss this point in greater detail.

Airy's theory was experimentally verified by Miller and Pulfrich with a cylindrical stream of water and a straight slit as the source of light. But the difference that may occur when the slit breadth is increased was not investigated. K. Aichi and T. Tanakdate extended Airy's theory to the case of a source of finite dimensions and thus explained away the discrepancies between Airy's theoretical deductions and facts of actual observation. In nature, for example, the principal bows are accompanied by a small number of supernumerary bows but Airy's theory gives us, as we have seen, a large number of them. The expression for intensity at a point P obtained by Aichi and Tanakdate is

$$I\ (\theta, \phi) = \text{const.} \left(\frac{a^7}{h^2 \lambda}\right)^{\frac{1}{3}} f\ (k, \phi, k\theta) \qquad \ldots \qquad \ldots \qquad (13)$$

where 2ϕ is apparent diameter of the source θ is the inclination with the ray of minimum deviation

$$h = \frac{(p^2-1)^2}{p^2(\mu^2-1)} \sqrt{\frac{p^2-\mu^2}{\mu^2-1}}$$

$(p-1)$ = number of internal reflexions.

$$f\ (k, \phi, k\theta) = \frac{1}{\pi\phi^2} \int_0^{\phi} \int_0^{2\pi} \left\{ \phi d\phi d\psi f^2 \left\{ k\ (\theta + \phi \operatorname{Cos} \psi) \right\} \right.$$

$$f^2 \left\{ k\ (\theta + \phi \operatorname{Cos} \psi) \right\} = \int_0^{\infty} \operatorname{Cos} \frac{\pi}{2} \left\{ u^3 - k\ (\theta + \phi \operatorname{Cos} \psi) u \right\} du$$

where $\phi d\phi d\psi$ is the elementary area of projection of the source on an imaginary sphere with its centre coinciding with that of the raindrop.

Thus it is seen that the function for intensity, *viz.*, f $(k, \phi, k\theta)$ is a function of k, ϕ and $k\theta$ and not of $k\theta$ alone as in the case of point source.

On discussion of this function the following results are obtained: (a) represents the case of a point source and (b) that of a circular source.

(1) The positions of maxima and minima of (b) nearly conicide with that of (a)— the first maximum of (b) is displaced by a small amount towards $\theta=O$ as compared with (a) and for other maxima and minima this displacement becomes smaller and smaller, but the maxima of (b) may correspond to minima of (a) and *vice versa.*

(2) The value of (b) corresponding to the maxima of (a) is smaller than that of (a) and the minimum value of (b) is greater than that of (a). This difference between (a) and (b) becomes larger with the larger diameter of the source.

(3) As the value of θ increases, the maximum value of (a) and (b) gradually decreases, while the minimum value of (b) gradually increases until it becomes equal to the maximum value and assumes a stationary value. Then the maxima and minima interchange, the difference at first increases and then decreases, then again assumes a stationary value and so on. If in this interval between the two stationary values the maxima of (b) correspond to those of (a), then in the next interval maxima of (b) correspond to the minima of (a).

(4) For larger values of a (the radius of drop) the intensity of (a) and (b) increases by $a^{\frac{7}{3}}$. But at the

same time for (b), the difference between the maximum and minimum values is diminished by another factor F.

(5) According to Airy's theory the law of distribution of colours of the rainbows is independent of the magnitude of the drop. But in the case of the finite source the colour distributions are changed by the magnitude of the drop, especially so in the supernumerary bows.

(6) The supernumerary bows almost lose the colour due to finite dimensions of the source, especially so when the drop becomes larger.

The abovementioned results have been verified by laboratory experiments with glass rods and a straight slit as the source of light.

I have given above a brief sketch of the rainbow phenomena as known at present and the attempts to explain them on theoretical grounds. But the list of possible phenomena may not be exhausted. As I have already remarked Nature knows no bounds and any one but a conservative observer is sure to claim for himself discoveries of new phases of what might be deemed a thoroughly established and commonplace phenomenon. Recently I had an opportunity of obtaining evidence in favour of this view and I now proceed to describe and discuss the new phenomena observed by me.

Some new Observations on Rainbows.

(A) *Polarisation of Rainbows.*

It is quite well known that the failure of Brewster's law, tan $i=\mu$ where i is the polarising angle and μ index of refraction, in case of several substances is due to unavoidable imperfections in the polish of the surfaces. Several years ago the late Lord Rayleigh showed by mechanical separation of surface impurities of water kept in a long metal trough that Brewster's law did hold good in case of water treated in this way.

On the morning of the 29th August, 1924, at about 6-15 A.M. when the sun was about 5° above the horizon, a strong primary bow attended by its strong secondary with the usual colour sequence was thrown on the western sky. No spurious bows accompanied any of the principal bows. Just before the appearance of these bows there had been one or two heavy showers and during the interval the bows were visible it was almost incessantly drizzling. When examined by a Nicol prism light from the bow appeared almost completely plane polarised. Assuming then Brewster's law and taking 1·33 as the refractive index of water for $\lambda = 5896 \times 10^{-8}$ cm., the angle of incidence $= 53°, 4'$ and angle of refraction into the raindrop $= 36°, 56'$ approximately. For one internal reflexion, *i.e.*, in the case of primary bow we can calculate the total amount of deviation which the incident ray suffers. It is 138°, 24' and it differs by 26' from 137°, 58' the angle of minimum deviation for $\lambda = 5896 \times 10^{-8}$ cm. calculated in the usual manner. Now the raindrops taking part in the production of the bows are for obvious reasons free from surface contaminations and thus the above observations appear to confirm in a novel way the late Lord Rayleigh's suggestion that in case of ordinary water the failure of Brewster's law is due to the attendant surface impurities.

Now since in direction 137°, 58' from the direction of incident light maximum intensity of light of wavelength 5896×10^{-8} cm. is received it must be the direction of the first maximum and is inclined at 26' with the Descartes ray. Using equation (10) an idea of the size of drops preponderatingly taking part in the production of the bow can be obtained. The value of the diameter of the drops thus calculated is about ·8 mm. This deduction gains support from the visual observation of spectral distribution in the primary bow which showed no spurious bows.

(B) *A Double Primary Bow.*

While the above observations were being made, a fresh bow parallel and close to the primary was suddenly developed. This had the same colour sequence as the primary and differed from the latter in intensity of colour and radius. The colour intensity as judged visually was slightly less and the radius slightly greater than that of the primary bow. But the most wonderful phase of this phenomenon was that the new bow gradually approached the primary and ultimately merged into it. The whole phenomenon took about 2 minutes for its completion. The light from the new bow as well showed almost complete plane polarisation.

So far as I am aware, there is no previous record of such a phenomenon and consequently it is likely to excite much interest and explanatory speculation. It may be suggested that of the two parallel bows just described one may be the supernumerary bow of the other. It is at once seen that this cannot be. The bow having the larger angular radius is out of question since the spurious bows attendant upon a primary have smaller angular radii. The bow having smaller angular radius showed greater intensity than the other one and so it cannot be a spurious bow. As far as I think the two bows are the two primaries of two different systems. The two primary bows may be explained by imagining two parallel rain showers from two gradually approaching clouds till one disappeared into the other. A simple qualitative experiment with glass spheres filled with water and a strong and steady source of white light was performed by me in the Physics Laboratory of the Allahabad University and it appears to lend support to such an explanation.

It will be interesting to carry detailed observation of all available rainbows from month to month and year to year. This may bring out any periodicity in rainbows and probably many other facts of which man is either partially or totally ignorant.

THE CRITERION

BY

P. S. BURRELL

The problem of the criterion is of universal and perennial interest. It is not only the central problem of Philosophy, but also the problem of which every human being desires to find the solution. It is one which concerns theory and practice alike. It is an especially burning question to-day, when all standards are questioned, the most cherished convictions are criticized and the very foundations of civilization are attacked. What is meant by the criterion? Fortunately we can learn something from language. The word is of Greek origin being derived from a word which means judge, and denotes that by which a thing is judged or decided: in other words a principle, or standard of measurement by reference to which the relative values of things may be determined. It therefore recalls the atmosphere of the Athenian law courts where it signified the organ of faculty or principle by which the Athenian juryman decided the cases tried before him. It is formed on the analogy of the word (αἰσθητηριον) which means the sensible faculty whereby we discriminate between the objects of the senses. Just as everybody has a faculty of distinguishing between sweet and bitter tastes, between light and heavy weights, between black and white colours, and so on, so the word criterion suggests that every man possesses a power or faculty or principle of distinguishing between non-sensible objects, *e.g.*, between truth and falsity, between the fair and the foul, between right and wrong. Let us illustrate the matter further by recalling the procedure in the law courts. A case comes up for trial, the business of the judge or the jury or both is to hear and sift the evidence produced for either side, to weigh the arguments advanced by the contending counsel, and to pronounce a sentence of guilty or not guilty. In other

words, the judge is expected to decide whether the witnesses have or have not spoken "the truth, the whole truth and nothing but the truth," whether the respective advocates have produced good or bad arguments, whether the accused deserves to be punished or acquitted. The task is one of dignity and responsibility, and accordingly the judicial office is invested with all the majesty of the law. Against the decisions of some courts an appeal is allowed to a higher court. Ultimately, however, the case is decided by the final court of appeal. The criterion then, in the legal sense, is the principle or standard of judgment by which the highest court arrives at its decision which is final. It is that which guides the decision from which there is no appeal.

It is not without a certain fitness that the imagery of the law courts has been metaphorically applied to the operations of the soul. Accordingly we speak of the tribunal of conscience: of the inward witness; of the account which a man must render of his thoughts and actions; of the reproaches and condemnations of his own heart. But the metaphor, like all metaphors, is only an analogy and an illustration: it is not a literal description of the unique transaction which takes place in the human breast. In the law courts the functions of the parties to the suit, the witnesses, the counsel, the judge and jury are performed by different persons. In the individual soul, there is only one party and he is also witness, accuser and judge all in one. But the important thing is the same in both cases—the sentence pronounced. Everything else leads up to the final act—the judgment. "There is," says Bishop Butler, "a superior principle of reflection or conscience in every man, which distinguishes between the internal principles of his heart as well as his external actions; which passes judgment upon himself and them, pronounces determinately some actions to be in themselves evil, wrong, unjust: which without being consulted, without being advised with, magisterially exerts itself and approves or condemns him, the doer of them accordingly."

That is the classical passage in which Butler asserts the existence of the criterion in the moral life and describes its character. The important points are that each man has a criterion, by reference to which he pronounces judgment, and that his judgment is final. If we extend the notion to life as a whole so as to include all the rational activities of man, to art, science, and religion, we can grasp the notion of the criterion or universal standard of judgment. The word criterion then draws attention to the important fact—that man is essentially a creature whose function is to judge, and one who judges for himself.

The same idea is expressed by the old scholastic definition "man is a rational animal." There are, of course, moments when one feels inclined to doubt its accuracy. If we accept it as true of ourselves, we are apt to condemn our fellows, whether individually or collectively, as sometimes highly irrational. At any rate, we should agree with Sir James Frazer when he writes "man is a very curious animal, and the more we know of his habits, the more curious does he appear. He may be the most rational of the beasts, but certainly he is the most absurd." But although, anthropology may serve the useful purpose of taking the conceit out of human nature, it never quite succeeds in shaking its obstinate faith in the old scholastic formula. We refuse to identify ourselves with the beasts that perish; and though we may accept the theory of the animal origin of the race, we maintain that, if we are only a little higher than the ape, we are none the less a little lower than the angels. In fact, we cling to our differentia—rationality. But, if so, the term must mean something far more than a mere cold intellectual capacity to calculate and argue. Certainly, the scholastics meant more: they meant what we should now call "spiritual"—that is to say, that a man is an artistic, scientific, moral, political, religious animal: a creature that can make objects of beauty and utility, can know the world outside him and the world within him, can act in combination with his fellows, can develope

a civilized life, and can worship the unseen. "Rational animal" includes *homo sapiens* and *homo faber*, man the knower, man the maker; it means both an intelligence and a will: a being who is capable of knowing, loving and realizing the good. Modern writers mean the same when they talk about values, variously designated spiritual, absolute, or eternal. If we ask them to be more explicit, they tell us of a kind of Trinity—Truth, Beauty and Goodness. These are the things, they say, that really matter; at all costs, they must be conserved, even though everything else melt into thin air, and leave not a wrack behind. They are sometimes referred to as ideals. Unfortunately, ideals are cheap nowadays: some people cant about them and some people rant about them. But it is to be feared, that they often remain vague and nebulous, and not a few would be non-plussed, if they were suddenly called on to formulate this Trinitarian creed or to produce a reason for the faith—that is in them. Still they would be in good company. When an eminent man was asked what religion he professed, he replied, "I believe in the religion of all sensible men," but when pressed to declare what that was, he answered "What all sensible men keep to themselves."

Now if the scholastic philosophers were right, they must have been optimists, for if all men are rational, they surely must be sensible, and as such they must have the creed of all sensible men. The vision of a world of sensible man holding a sensible creed, seems, however, to clash violently with the facts. Some people stoutly deny they have any religion at all: and professed religions exhibit an extraordinary diversity, including some which are absurd, immoral or revolting. It would certainly not be easy to harmonise them into a sensible system. Is then the optimism of the scholastics untenable? If we are tempted to think so, let us remember that the religion of an individual or of an age is not the same as its nominal creed: that men's faith is often better than their practice: that they sometimes mean more than they can say. The principles

or ultimate values may be all the time implicit in the mind and heart of a man, even though he has often failed to realize them in their full meaning or to give them articulate expression. Some may bury them in a napkin and make no use of them: others may have no gift for speech and though they can act upon them cannot talk about them: others like the mystics may be conscious of thoughts which are too deep for words. Still, it is the business of philosophy to make explicit the implicit principles of thought, and therefore one of its tasks is to give intelligible significance to the scholastic notion of rationality and the modern concept of spiritual values. I suggest therefore that what these terms mean is that man is in possession of a criterion or ideal, a principle of judging between truth and falsity, fair and foul, good and evil: or, as we may otherwise express it, a standard for measuring logical, æsthetic and moral values. That is the universal and essential characteristic of man, without which he would not be a man at all.

So far we have been occupied with the definition of terms, we must now turn to the more difficult question—the meaning of the terms. For suppose an inquisitive person asks us, Yes—But *what is the criterion*? we should be hard put to it to find the answer. At least, that is the experience of philosophers and the world in general. And our inquirer might go on to say that "it is nonsense to talk about *the* criterion, for its name is legion. It would be more correct to speak of *criteria* in the plural. Is it, for instance, to be found in the past or in the present? Crabbed age and youth give different, nay, opposite judgments, and the children of the latter in their turn may describe their fathers as back numbers. The chimera of yesterday is the commonplace of to-day, and may become the laughing-stock of to-morrow. Early Victorian is to-day one of the commonest terms of reproach, and the 21st century may consider the 20th hopelessly out of date. But not only does the criterion seem

to change from age to age, it also changes from place to place and from man to man in the same generation. So many men, so many opinions—says the proverb. Nay more, it is not a fixture even in the individual: he may be "everything by starts and nothing long" from the cradle to the grave. A cursory glance at history and the contemporary world suggests that the criterion is a veritable chameleon, which changes its colour every moment. How then does it differ from fashion or opinion or random caprice?

It is easy enough to make out a plausible case against the propriety of talking about the criterion in the singular. It appeals to the popular imagination, and philosophy does not come promptly to the rescue. For, from its earliest dawn, philosophy has been struggling with the same difficulty. Always the battle has raged round the question whether there are criteria or only one criterion; and it still rages. We can watch its progress from the time of Heraclitus proclaiming that "all things flow and nothing abides," of Protagoras, teaching that "man is the measure of all things," to Bergson's philosophy of change, and the Pragmatist who flatters us that truth is what we will to make it. We seem, in fact, to have on our hands the old problem of the one and the many. If there is only one criterion, how can there be many criteria? and conversely, how can there be one criterion, if there are any number of criteria? Is the one incompatible with the many? and can the many subsist without the one? It is a very pretty problem. But, at least, we can say at this stage to the partisans of the many criteria, that however much appearances seem to be on their side, it would be somewhat remarkable to allow us to decline the plural and yet forbid the use of the singular. It may be that without the latter the former is neither possible nor intelligible. Meanwhile, we can see, that the question of the *existence* of the criterion is bound up with the question of its nature or essence. "What is the criterion?" The fortunes of existence and essence are

inseparably connected. For it was the question, *what* is the criterion, that raised the doubt whether it is one, rather than many. If therefore we can answer that question, we may also find out whether it exists or not. If we can say *what* it is, we may be able to say *that* it is; and we may do more, we may find out also its worth or value, for that will consist precisely in being what it is. Thus the three questions—of existence, "is there a criterion?"; of essence "what is its nature?" and of value "what is the good of it?"—are all part and parcel of one and the same problem.

It is an extraordinarily perplexing situation. How can we establish the existence, explain the nature and demonstrate the good of a principle the very existence of which is doubted or denied? Let me illustrate by reference to a famous discussion of the moral criterion or principle. In the *Republic* of Plato Socrates undertakes to find what the principle of justice is. But he is met at the outset by cynical denials of its existence. What is the good of finding what justice is, if there is really no such thing? It is obviously no good, unless he can kill two birds with one stone: that is to say, unless the same argument that demonstrates its *nature* proves its *existence* at the same time. Now that is what Socrates does. He shows that justice is the principle of health and strength in the soul and in society. As the existence of such a principle cannot be doubted by his opponents, it follows that justice is a reality. And what is more, its value needs no demonstration, for that consists precisely in being what it is, viz., the principle of individual and social health and strength.

Let us adopt, then, the method of Socrates and inquire *what* is the criterion? Perhaps we shall gain some light by cross-examining the more important answers that have been given and can still be given to this question. This will enable us to clear the ground and ascertain the right answer if there is one, to our question. Some

of them need not detain us long. But first let us consider what an immense boon it would be, if we had at our disposal a thoroughly reliable criterion or standard of value. How useful it would be if we could know the real truth about our neighbours and how useful also, as our neighbours think, if we could know the truth about ourselves, or at least could see ourselves as others see us. We should all know whom to trust and whom to beware of? Again we hear much to-day about the standard of living. The wage-earner cries out for a living wage: a serious matter in a time of high prices and heavy taxation. The employer says that he cannot afford to meet the demand. And the difference of opinion leads to heart-burning, strikes, dislocation of trade, wide-spread suffering. What a world of trouble and misunderstanding would be saved if both parties knew what constitutes *the* real standard of living.

Once more, when we talk of the living wage or the standard of living, we think not so much of life or living itself as of its conditions and specially of its material conditions—of those things whose value can be measured in money. We often forget the profound difference between the two—that life is more than meat or raiment or the whole external paraphernalia of civilization. These are means and not end; but as Stevenson says somewhere, the occupier of the tenement is a subject of far more interest than the tenement itself. The really important and literally vital question is what is the standard of living as such? What is the true life or the best life for man, as such, to lead? How shall each of us order our lives so as to "walk surefootedly in the world" and advance on the road which leads to perfection? If we knew the true good, then we should be in a better position to realize the good. If virtue *is* knowledge, according to the Socratic maxim, the knowledge of the criterion or true standard of life would secure us from much folly and wickedness and misery.

But alas; the plain fact is that we have no universally accepted first principle. There seem to be all sorts of standards struggling for the mastery: pleasure, riches, honour, power, virtue: each of them claims to be the supreme good or final standard of value. The one thing needful both in theory and practice is to settle their claims by discovering the true criterion or first principle. It is the first step which costs: if we only can lay a firm foundation, we can build a durable and comfortable edifice.

That is what Socrates means when he says that the most important thing, about everything whatsoever, to discuss and enquire, is whether the first principle has been rightly established or not, otherwise, we shall be like a mathematician who makes a false start in his demonstration and then the greater the consistency of his reasoning, the further does he depart from the truth. He is like a man walking in the direction exactly opposite to his destination.[1] "What profit," says Newman, "though ninety links of a chain be sound if the topmost is broken: ultimately authority is needed to make it trustworthy." And Tennyson puts the practical aspect of the question still more forcibly:

> "Hold thou the good; define it well:
> For fear divine philosophy,
> Should push beyond her mark and be
> Procuress to the lords of hell."

Now, it is easy enough to reject what is *obviously* false, or ugly or evil: the difficulty is as the advertisers warn us to beware of shams and substitutes and imitations. We can shut the door on the wolf undisguised—but we are liable to be deceived by him when he comes to us in sheep's clothing. The difficulty is to distinguish appearances from the reality, which alone can give us satisfaction. "Is it not evident," says Plato, "that many people will choose what seems just and

[1] Plato, Cratylus, 436d.

beautiful and will be content to do and have what seems so, even though it actually is not just and beautiful ? But seeming good never yet contented any man. Here all seek reality and the semblance is treated by every one with contempt. But if we don't know the real good, though we should have the fullest knowledge of everything else, that would be no use to us, any more than is the possession of anything without the good."[1]

Let us now return to examine some of these semblances of the first principle which we all want. To begin with it is natural that the word first should be given a temporal significance. One of the most important events in a man's life is the first, *viz.*, his birth, and it is not surprising, therefore, that primitive man should have distinguished people into good and bad according to their birth and made birth the standard of value. Nor has the notion become obsolete: for race, nation, caste and class still seem to play a great part in determining a man's angle of vision. It clearly makes a great difference whether a man is born on the banks of the Ganges, or of the Thames, or of the Mississipi, or in Timbuctoo, whether a man is "a duke's son" or "a cook's son." We do not know whether men are *born* co-operators or non-co-operators or only become so; but the late Mr. W. S. Gilbert pointed out in well-known verses "every man alive is born a little Liberal or else a Conservative" and Few would question the truth of the proverb "Blood will tell." Nevertheless the aristocratic criterion as it might be called is obviously inadequate. If birth is an event, it is also an accident; something that does not depend on ourselves, and we do not want an accidental criterion. Besides this criterion lacks permanence: for the little Liberal may grow up into a Conservative and *vice-versa*, or he may even become a red-hot Socialist. Moreover it is obviously not ultimate, for we require a further standard for measuring the

[1] Republic of Plato, 505E.

values of these rival standards, to adjust the respective claims, let us say, of order and progress, of law and liberty. And Thomas Hobbes settled the question by his epigram: "good counsel cometh neither by lot nor by inheritance."

Next let us consider the criterion of tradition or custom, *i.e.*, the authority of our ancestors. Reverence for custom may be a form of ancestor worship, which some anthropologists affirm to be the source of religion. It is at any rate regarded as an aspect of piety, and invested not only with religious sanctity but with social sanctions. The formula is "*this* has been done," "therefore it must be done"; "*that* is not done"; "therefore it must not be done"; it is taboo, and the transgressor gets into hot water with the elders of his tribe, who may chop off his head or show their displeasure in some equally disagreeable manner. There is much to be said for this criterion: "traditions in nations, it has been well said, are like habits in the individual." And Plato points out that the beliefs about the just and beautiful in which we have been brought up from our childhood are "like parents to us and we obey and honour them."[1] But clearly traditions, like habits, may be good or bad; they may be called in question and then we require a principle to decide their value. Moreover, the facts are too much for the permanent dictatorship of custom and tradition. The world does not stand still: history does not repeat itself: unprecedented situations arise. As the poet says, "New occasions teach new duties, Time makes ancient good uncouth." So the formulas have to be stretched and often break in the process.

Again as the means of communication are multiplied, different peoples mix together; they become acquainted with strange unfamiliar customs: and they find that, though natural agents behave uniformly everywhere, the standards of human conduct not only vary, but conflict. Herodotus gives a strik-

[1] Plato's Republic, 538C.

ing illustration: "Darius, King of Persia, after he had got the kingdom, called into his presence certain Greeks who were at hand and asked, 'what he should pay them to eat the bodies of their fathers when they died.' To which they answered that there was no sum that would tempt them to do such a thing. He then sent for certain Callatians, men who eat their fathers, and asked them while the Greeks were standing by, and knew by the aid of an interpreter all that was said, 'what he should give them to burn the bodies of their fathers at their decease?' The Callatians exclaimed aloud and bade him forbear such language."[1] The comment of Herodotus is: "such is the way of men and Pindar was right in my judgment when he said 'Convention is king over all.'"

As a matter of fact the differences of custom suggest just the opposite inference to an inquiring mind, which argues, "if custom is a house divided against itself, how can its kingdom stand." When this conclusion is reached, the belief in the final authority of tradition is shaken for ever, and the only alternatives are moral anarchy or the discovery of a foundation deeper than convention. Tennyson wrote the epitaph of tradition in the familiar lines:

> "The old order changeth, yielding place to new,
> And God fulfils himself in many ways,
> Lest one good custom should corrupt the world."

Tradition, then, is not the criterion we are in search of: for it is local, temporary and fluctuating. We seek something universal, abiding and impregnable.

Let us now turn to the democratic standard: in other words, public opinion. It is extremely fashionable and often proclaimed as the master-light of modern seeing. If you are in doubt which mob to shout for, Mr. Pickwick told us, the wisest course is to shout with the loudest. Modern psychology will tell you that in so doing you are obeying an impulse

[1] Herodotus, III, 38.

more fundamental than your rational nature. It is the group instinct of the herd, which makes the sheep follow their leader and the wolf hunt in packs. Even the anarchists or the Bolshevists who burn to assassinate the social order, cannot escape from it; they rage furiously together in Soviets. The democratic standard is variously described: "The voice of the people is the voice of god": "the general will," according to Rousseau, is infallible: "The right of the majority is divine." Thus, public opinion is invested with a halo of religious sanctity: the politician pays it adroit flattery and the popular newspaper becomes the oracle of divine wisdom. Evidently, it requires much courage of heart and independence of mind to refuse to bow down to the golden image which demos has set up. There is, of course, a good deal to be said for it. Take, for instance, this fable of a humorous writer:

> "The poet wrote a song, making out of the suffering of his own heart his message to the world.
> The man of Business read it and shook his head. For there was no money in it.
> The man of Action was busy with a machine-gun and could not be bothered with poetry.
> The Scholar pointed out that the song did not conform to the best classical examples, and contained metrical defects.
> The ordinary man took pride and pleasure in saying that he could not make head or tail of the song.

And then the poet found a blue-eyed maiden, who knew nothing of money or machine-guns or pedantic rules, and had not lived long enough to become quite ordinary, and to her he read his song. 'And what do you think of it, little girl?' he asked. 'Well, speaking frankly, rot,' said the little girl."

The moral is this: "the fact that your work is greeted with general neglect or disapproval does not necessarily mean

that the other people are wrong."[1] That of course is a perfectly correct conclusion. But neither does it follow that the other people are necessarily right. For it is just possible that the poet had composed an immortal work which the world of his day failed to appreciate. At any rate, it has never yet been demonstrated that the truth can be found by counting heads, any more than by breaking them: and the standard is always exposed to the fallacy of the odd man. If 501 persons believe that black is white and 500 believe that it is not white, it is not easy to see why the opinion of the former should prevail rather than the other.

So far from the opinion of the majority being the truth even the universality of a belief is an insufficient guarantee. Before Copernicus everybody believed that the sun revolved round the earth, yet it was no less true before his day than it is after it has been proved that precisely the opposite is the case. Moreover, minorites have always asserted the right to exist, and when a minority not only survives but actually governs by virtue of heading the poll, like the late Labour Government, the orthodox democratic creed seems to be in serious disrepair and in need of revision.

But these are general, abstract considerations. More serious objections are furnished by the facts. History records numerous cases of the crowd acting foolishly, and nations like individuals, seem to be sometimes afflicted with madness. Honest men have been found to defy the multitude and such are the men whom the world has delighted to honour. "Athanasius against the world" has passed into a proverb and Socrates cuts a finer figure in history than the Athenian democracy which condemned him. Sometimes these men have had to resist to the death. What has nerved them to face the ordeal? Evidently some criterion, the knowledge of true values, "indefectible certitude," as Newman called it, "a

[1] Barry Pain in "The Blinded Soldiers' and Sailors' Gift Book."

divine sign," as Socrates called it, must have supported them in the hour of trial.

> "It fortified their soul to know
> That, though they perished, truth is so."

The democratic standard, then, will not suffice. Numbers, as such, can be no criterion of truth. The agreement of many minds in one view may afford a strong presumption of its truth. But the reason lies not in the number, as such, but in the fact that the view persists through such a diversity of opinions, feelings and circumstances. The general opinion is valuable only so far as it represents the deposit of accumulated and tested experience and reflects what Burke called "the wisdom of the ages." If it represents the preference of a scratch majority, of the passing hour, of a class, or even of a generation, it may be the agreement of many minds in a falsehood, which it is the duty of an honest man to reject. The appeal to general experience, to the opinion of the multitude, or to the common sense of mankind is not the appeal to an ultimate authority; for that is required to distinguish the truth which lives in the general heart and mind of man from the appearance of truth proclaimed by a fortuitous concourse of individuals. Without that the position is aptly described: "I thought the world mad, and the world thought I was mad. And confound it, they outvoted me."

We have now reviewed various criteria, which we may call the judgment respectively of the best heads, the old heads and the many heads, and we have found them all wanting. There is still an alternative left, the wise heads—the experts. That is the refuge of the man who seeks the shelter of a guide, philosopher and friend. He is attracted by the authority of a great name, of the preacher of a new gospel, the founder of a great system or a powerful organisation. He believes his teacher or leader has said the last word on politics or literature or religion or philosophy,

and is prepared to back his side against all comers. He becomes the enthusiastic disciple, let us say, of Carlyle, or Herbert Spencer or Karl Marx; he swallows the monism of Hegel or Bradley and worships the Absolute: or he becomes a pluralist with William James, and derides a "block universe." But the old difficulties recur. The doctors disagree and both have a good deal to say for themselves: and the disciple finds differences even in the same camp. Suppose he decides that the Absolute solves the riddles of the Universe; whilst Mr. Bradley tells him it contains all the treasures of truth, beauty and goodness; Mr. Pringle-Pattison tells him that it is "neither personal, nor moral, nor beautiful, nor true—" "a mere cluster of negations." The Scotch Philosopher, Mr. McTaggart, says that the belief in immortality, though it makes a difference in our estimate of man's place in nature and therefore, in our ideals, aspirations and hopes and "the emotional colouring of our lives," it makes no practical difference in the performance of our daily duties. It does not, for instance, influence us in deciding whether or not we shall pay our bills, cheat at cards, or betray our country. The English Dr. Johnson, on the other hand, tells us that if one of our guests at dinner proclaims his disbelief in immortality, we had better look after our silver spoons. How is the perplexed student to decide between these eminent authorities?

Or again, suppose he is inclined to applaud Mr. Spencer's reconciliation of the alleged conflict between religion and science by deifying the Unknowable, he will be puzzled to find Mr. Bradley telling him that Mr. Spencer seems to have set up the Unknowable as God, just because he did not know what the devil it could be. Illustrations could easily be multiplied.

The position is certainly embarrassing. The disciple is an earnest seeker after truth—and he accordingly betakes himself to the pandits, the teachers who claim to know, in order to hear what they have to say about it. *Ex hypothesi*, he is

consulting those who are wiser than himself. To consult them all would be an endless task, for life is short and art is long. But even if he could, would that be the true path to knowledge? Socrates thought it was not, asserting that such a procedure could only lead at the best to *true opinion* which was a long way short of true knowledge. And he compares such a seeker after truth to the judge in a law court listening to evidence and argument. In a legal trial the business of the advocates is to persuade the judges of the truth about what has happened to people who have been, for instance, robbed of their money, or otherwise injured when there were no eye-witnesses. We know that in practice the judges are sometimes wrongly persuaded owing to perjury or fabricated evidence in which case there is a miscarriage of justice, but even if, as Socrates says, " they are justly persuaded about matters which one *can know only by having seen them and in no other way*, then in such a case they judge only from hearsay; they have acquired only a *true opinion* about the facts; they have judged without knowledge."[1] And therefore he says if true opinion and knowledge were the same thing in the law courts, the best of judges could never have true opinion without knowledge: But, in fact, Socrates concludes "it appears that the two are different." And he compares those who unintelligently believe what is true to blind men going on the right road.[2] Here Socrates goes to the root of the matter—the best "judge," the most earnest seeker after truth, who only listens to the evidence of others, even of the most authoritative unimpeachable witnesses, can never acquire genuine first-hand knowledge but only *true opinion* based on testimony *because he has not himself been an eye-witness of the matter under investigation.* Only if he can see for himself with his own eyes, has he got *within himself* an infallible criterion for deciding between the

[1] Theaetetus, 201.

[2] Republic, 506C.

accounts of it presented by the different sides. The mortal defect of all the criteria we have examined is that they are *external :* they all require that a man should submit himself to some authority outside him, whether it be aristocratic or traditional, or democratic, or the expert witness, or what Stevenson calls, "some crack-jaw philosopher." As Richard Mulcaster said, "It is not because a writer said so, but because the truth is so and he said the truth. The truth gives him title and that is it which must pass strong enough of itself and oft-times weakened in the hearers' opinion though not in itself by naming the world." And the pith of the matter is expressed in the reply of Sir Thomas More when tempted to bend his conscience to the opinion of the man he most revered. "I will not pin my faith to any man's back, not even the best man living, for I know not how far haply he may carry me." Now, if an external criterion is unsatisfactory, there is only one alternative; the criterion must be *internal*, needing no external guarantee; it must have its evidence in itself, a man must rely on the inward witness, the witness of his own soul. He must take his courage in his own hands, put confidence in himself, and trust his individual private judgment.

But does this solve our problem? On the contrary, at first sight, difficulties seem to thicken and confusion to be worse confounded. When every honest man knows that he is weak, thoughtless, erring, untrue, how can he presume to find in himself the witness to the absolute and eternal values. If a man is a law unto himself, can he not do what is right in his own eyes? Does this not pave the way to a complete spiritual anarchy? Let us take stock of the situation. If each individual subject possesses the criterion of truth, then truth in some sense at least depends on himself. That is the creed of subjectivism, that there is no common standard, and every one has a perfect right to think and act as he likes. What is true for Tom, may not be true to Dick, or Harry, unless perhaps by accident. Each has a different angle of vision, and what they

see is different in each case. Or. we may call the creed relativism. That is to say, there is no absolute truth—the same for all alike, truth is only relative to each individual. Or again, as the Pragmatists hold, truth is not something public and abiding, open to the investigation of all: The problem is not truth-finding, but truth-making—and we make it what we will according to the way it works for us. Truth is only another name for expediency and there is nothing to prevent the truth which I make being extremely unlike the truth you make —and so on *ad infinitum*. Truth is something which *happens* to an idea: it is, therefore, something accidental, not necessary or universal. It is, as it has been wittily said, like the credit of a bank which rises and falls, and, of course, may disappear altogether if the bank breaks. Truths and beliefs "pass," as long as nothing stops them, just as bank notes "pass" so long as no one refuses them. If these creeds are true, then obviously the criterion changes from individual to individual: and the only constant characteristic of truth is its constantly changing nature. The pursuit of it is, therefore, as fruitless, as Aristotle suggests, as "to run after birds on the wing."[1] Now the difficulty is not a new one, as the names subjectivism, relativism, pragmatism suggest. On the contrary, it is very old, perhaps as old as human nature, and it confronted Socrates in perhaps the acutest form it has ever assumed. It is worth while therefore to see how he tackled it. Metaphysically, it confronts us in the Heraclitean doctrine of motion—"all things flow and nothing abides." Epistemologically, in the sensationalist doctrine that "knowledge is sensation": In its practical form in the doctrine of Protagoras—"man is the measure or standard of all things." These are, Plato tells us, all different expressions of the same doctrine, the confutation of which constitutes one of the landmarks in the history of thought.[2]

[1] Metaphysics, IV, 5.

[2] Vide Plato, Theaetetus.

The doctrine of Protagoras is based on such familiar experiences as this: that sometimes when the same wind blows, one of us feels cold, and the other does not; or one person feels slightly cold and another exceedingly cold. And Protagoras points out that everyone is the best judge of his own feelings in such cases. The wind is cold for him who feels cold and not for him who does not. The appearance *is* the reality. His perception or feeling is always of that which exists, and since it is knowledge, it cannot be false. Now apply this principle all round, to all experience, and it follows that each man's outlook on the universe is unique, and infallible: in a word, all men's opinions or experiences are equally true. Apply the principle to the sphere of conscience and conduct and you see at once how devastating are its consequences. That is the dangerous but plausible theory which Socrates undertakes to overthrow. Let us follow the main steps in his argument.

(1) First of all, the maxim, "man is the measure of all things," proves too much. If what appears to me, *is* true for me and what appears to you is true to you, and so on, for everybody, then we have no business to restrict its application to human beings. For things also appear to all sentient beings: Protagoras ought, therefore, to have said, not, "man is the measure of all things," but "a pig or a dog-faced baboon or some still stranger creature of those that have sensations, is the measure of all things." Man has no more and no less hold upon truth than a caterpillar. That is a palpable hit which made Protagoras forget his manners. He became abusive, and retorted that Socrates had argued "in a piggish way"; but he could not refute him.

(2) Secondly, instead of explaining things, it explains them away. The problem starts from the general belief that some opinions are true and some are false; that is why people are so anxious to find out the truth and avoid the false. Protagoras professes to explain the nature of truth; and his explanation is that everything is true: that it is impossible to

question the truth of any man's opinion, for each man is himself the final court of appeal. But if all opinions are equally true, none can be false. If everything is right, nothing can be wrong; the distinction of truth and falsehood vanishes. But in that case what is the good of taking the trouble, like Protagoras, to explain what truth is, especially when every one knows what it is already and does not need to be told. This may be an ingenious method of cutting the Gordian knot, but it is an explanation which is no explanation.

Obviously, then, if you are going to explain what truth is, you must also explain what falsehood is. *Any explanation of truth which destroys the existence of falsehood is out of court.*

The issue is "are all the opinions of all men always true?" as Protagoras asserts, or "are they sometimes true and sometimes false?" as commonsense holds. If Socrates can show that it follows from the Protagorean doctrine, no less than from the commonsense view, that opinions may be true or false, he will prove his point. In a word, in order to upset the view that "all opinions are true," he has to demonstrate the existence of falsehood. This he proceeds to do.

(3) Let us grant then for the sake of argument that "all opinions are equally true." Protagoras knows, as we all do, that many persons do not share his opinions. Commonsense, for instance, denies it. But if things are to each man as they appear, then, the opinion of the man who disbelieves and denies the Protagorean doctrine is just as true as that of Protagoras himself who believes it. So that the Protagorean doctrine that "all opinions are equally true" necessarily involves its own falsity; that is to say, the denial of the existence of falsity, implies the assertion of its existence. Protagoras is convicted out of his own mouth; for in confirming the opinions of those who contradict him he confutes himself. He is like an engineer hoist with his own petard. His theory explodes itself. If it is not true, it must be false. Therefore

the very doctrine that proclaimed that no opinion is false is a standing witness of the existence of falsehood, for it is itself false. It affirms what it professes to deny. Socrates has clearly dealt Protagoras a knock-out blow, from which there is no recovery. He has shown that the theory refutes itself. So far from Protagoras having proved that all appearances are real, that there is no difference between appearance and reality, he has produced the most startling evidence that some appearances are unreal: for what *appears* to him has proved to be a misrepresentation of things as they are. This false friend of truth, who professes to vindicate truth, by asserting that lying is impossible because no men are liars, is convicted out of his own mouth of being a liar himself.

(4) But not only is the doctrine theoretically unsound, it will not work in practice, and in particular it is in glaring contradiction with his own conduct. For Protagoras was a famous teacher: if he obliterated the theoretical distinction between truth and falsehood, he did draw a distinction between better and worse. He regarded himself as a sort of moral physician, who could make the worse appear the better reason. Just as a doctor makes his patient better in health, so Protagoras by the art of rhetoric or persuasion undertook to transform a diseased state of mind, *i.e.*, one which holds worse opinions, into a healthier state. Moreover he wrote his book on Truth to make people wise on the subject. But if all opinions are equally true, then every one knows the truth to start with, without going to the expense of buying Protagoras' book or taking the trouble to read it. That would be like taking coals to Newcastle. Thus, Protagoras' theory is inconsistent with his practice. Socrates completes his victory by demolishing the metaphysical basis of the doctrine, but it would take too long to reproduce his argument. Suffice it to say that he shows that it makes all judgment, including the maxim of Protagoras, and all significant speech impossible: and that involves not a world or

cosmos but an indescribable chaos, in which there are neither persons nor things nor qualities, no one to know and nothing to be known: thus the bankruptcy of logic and morals is only the counterpart of a metaphysical nihilism.

It remains for us very briefly to estimate the value of Socrates' achievement. He who devoted his whole life to the pursuit of truth in thought, speech and action had been challenged by the doctrine of an illustrious thinker which by affirming all opinions to be true amounted to doing away with truth altogether. Unless such a doctrine could be overthrown, it would mean that Socrates had thrown his life away. But it can be overthrown if he can make Protagoras in his own person admit that his much-vaunted doctrine, that apparently solved so easily and triumphantly all the problems of the universe, is not true but false. This he succeeds in doing and somewhat paradoxically establishes the certain existence of truth on the certain fact of falsehood.[1]

The possibility and the existence of falsehood, in fact, is the guarantee of truth. But this is a "paradox which comforts, while it seems to mock." For it assures us that, if ever we should be tempted to embrace the doctrine in any of its various forms, scepticism, agnosticism, relativism, subjectivism, naturalism, pragmatism, and so on, viz., that truth and reality are non-existent or unknowable or an accidental or arbitrary product, we may reflect that if we are not in possession of the whole truth, truth in full, we at least know enough to be able to say, that some opinions are false, and similarly, as we distinguish between true and good and seeming good, between real beauty and seeming beauty, we must know enough

[1] It is noteworthy that the Socratic method is the exact opposite of Mr. F. H. Bradley who writes "before we deal with error we must gain some notion of what we mean by truth"—Appearance and Reality, p. 162. If he had begun the other way round, he might have reached very different conclusions.

about the good and the beautiful to reject the evil and the foul. We are not the prey of every passing impression or impulse; we are sure that certain opinions are false: and we cannot do this without possessing the criterion, for the only justification for recognising and condemning the false, is the knowledge of the truth. We could not reject appearances as false unless we could apprehend the reality they misrepresent. But it will be said: "Such a criterion is only negative." We desire not only to recognise and reject the false, the foul, and the evil, but positively to know and realize the true, the beautiful and the good. Fortunately we can derive comfort from the reflection that every negation implies an affirmation, and that all significant denial implies a real positive. We cannot intelligently say "no," unless there is something, however dimly we may be aware of it, to which we should and must say "yes." Though the knowledge that expresses itself in negations is indeterminate and indefinite, it is capable of development into something definitely positive. And such negative knowledge is of higher value. The conviction that "the theory that all opinions are equally true" is not true but false, is a secure foundation on which to rear the fabric of science. It is also a safeguard against spiritual pride—the belief that one knows when one does not—which the maxim of Protagoras "each man is the measure of all things" directly fostered. By reminding us that we may be mistaken, it inculcates a proper humility which is the indispensable first step in intellectual and moral progress. Man's consciousness of truth whether in the individual or in the race may at first be dim, his grasp may be feeble, the light that is in him may be almost indistinguishable from darkness, but if it is really there and he trims his lamp faithfully, it must and will burn ever stronger and brighter. "Truth is great and will prevail."

Plato himself has provided a happy illustration of the positive value of negative knowledge and negative logic. In

the *Republic* Socrates asks "what is justice?" He is told that it is "paying back what does not belong to you and not telling lies." Very well, he replies, If you borrowed a two-edged weapon from a man in his senses and he then went out of his mind and asked you to return it, would you give it him back? Everyone would say, no. What then is the justification for violating the formula.? Obviously because we know that it would be *good* neither for ourselves nor for the owner of the sword nor for anyone else to put a sharp-edged weapon in the hands of a lunatic at large. That is to say, we have an idea of good, which deters us from a harmful action. We have only to develop that germ of knowledge, the instinctive apprehension of the good; and, it will lead to the full positive definition of justice as "the doing of one's duty," which is the principle of life and health in the soul and in society. And that is what Plato does in the *Republic*. The negative knowledge rests on a positive basis which it is the object of philosophy to make explicit.

It was said of Socrates that he did not define the good. Neither did he define knowledge, though he spent a long life enquiring into their meaning, and his fundamental doctrine was that "goodness is knowledge." Why did he leave them undefined? For a very simple reason: they are both indefinable. You cannot define what is the presupposition of all definition. Further, the knowledge of truth and goodness and beautiful cannot be derived from others. It cannot be neatly tied up in paper parcels and exchanged over the counter for a consideration. It must be sought by each in his own soul by the process of cross-examination and earned by the sweat of a man's own brow. That is why Socrates preached always on the Delphic text "Know thyself." This is commonly interpreted to mean, "Realise your own limitations: recognise the scantiness of your own mental furniture." And certainly Socrates did mean that the consciousness of ignorance—"knowing well that one does not know," is the one lesson

worth learning. But he did not mean anything so discouraging as the view that the soul is not worth knowing. On the contrary, he believed that everyone has a self—a belief which many have doubted or denied—and that that self is worth knowing and can be known. And accordingly he made it the business of his life to persuade people to " care for their souls." " I go about, " he said, "doing nothing else but urging you, young and old alike, not to care for your bodies or for money sooner or as much as for your soul, and how to make it as good as you can."[1] He recommended them in fact to undertaking the extraordinary feat of making an expedition into their own interior, in order that by examining themselves, they might become conscious of the truths with which the soul is pregnant : and he practised his art of intellectual midwifery to assist men in bringing the truths, which they have conceived in their soul to birth, meaning by the soul " whatever it is in us that has knowledge or ignorance, goodness or badness." Socrates was bound to insist that it offered the most fruitful line of research both for theory and practice, for without the light derived therefrom, man is only groping in the dark. Above all it is necessary to discover those first principles of knowledge and conduct, which will enable us to overthrow the enemies of truth, like Protagoras and his disciples. Nay, more, we shall not only vanquish them but make them willing partners in our victory : for the battle is won only by bringing to light the presuppositions and first principles, which are common to him and ourselves and every rational animal and which therefore they must admit, as soon as they are brought to see them, as their own. Those principles too are shown to be impregnable, because it is impossible even to doubt or deny them without assuming them. All this means that man cannot find the criterion—the final standard of value—by exploring the face of the planet,

[1] Plato's Apology, 30a.

by dredging the deep seas, by gazing at the starry heavens, or even by studying the experiences of his fellows.

Man has the criterion in himself : he is himself in direct immediate touch with reality : he contains in himself the seeds of truth. It is alike his duty and his prerogative to make them germinate and spring up, and bear fruit to perfection.

THE SENSIBLE APPEARANCE OF MOVEMENT

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A text for this topic is furnished by cases of paralysis of the rectus muscle of either eye. If the external rectus muscle of the right eye is paralysed so that the eye can no longer be rotated outwardly (to the right), then, when the patient tries to rotate it outwardly, the eye does not move, and of course the retinal images do not move to the left across the retina (as they would if the eye actually moved), but remain stationary. But objects appear to the patient to move to the right. If the images had actually moved to the left as they ought to have done if the rectus muscle had done its work, the objects would have been perceived as stationary. But, the images being stationary while the patient has *willed* to move his eye to the right, he perceives the objects as *moving to the right:* which is the only objective condition which could have produced a stationary retinal image if the eye had actually moved to the right. The patient sees what he *ought* to see under the conditions. This furnishes a sufficiently striking example of a sensible appearance of movement which is independent of any "primitive retinal sensation" of movement: for here a stationary image gives the "impression" of movement. It also exemplifies that power of expressing meaning which makes the sensible appearance in each particular case just *that* and no other appearance. For the movement perceived (movement to the *right*) is just the movement required to express or interpret a supposed set of objective conditions, *viz.*, stationariness of image

combined with eye-movement to the right. As it happens, in this case, the "unconscious inference" is wrong, because one of the "premises" is false.

In this particular instance there has been a controversy as to what the determinant conditions of the sensible appearance are. "Kinæsthetic sensations" appear to be excluded by the fact that the eye does not move: and the champions of the "innervation feeling," as James says, regarded these cases as an *experimentum crucis* in favour of their hypothesis. But their argument is met by pointing out that the other eye executes sympathetically the movements which the paralysed eye fails to execute, and so provides the necessary kinæsthetic impulses.[1] But this retort has again been very neatly turned by a recorded case of paralysis both of the external rectus of the right eye and of the internal rectus of the left eye: in which case, of course, neither eye can carry out the intended movement. And yet the same illusion of movement or displacement of objects to the right was found to occur.[2] The facts would seem therefore to point to Dr. Myers' conclusion that the act of volition co-operates with the retinal impression to determine the sensible appearance in these and similar cases.[3] Thus it

[1] James, *Principles of Psychology*, Vol. 2, pp. 507, *et seq.*

[2] Myers, *Text-Book of Experimental Psychology*, 2nd Edition, 1911, p. 215. Myers speaks of "apparent displacement of the visual field" evidenced by the subject's localising objects too far to the right when he tries to touch them with his hand. But Helmholtz is quoted by James (Vol. 2, p. 507) as saying that the objects "appear flying to the right."

[3] Dr. Myers points out a similar instance of illusion determined by an intended but not effected muscular contraction, in the case of micropsia beyond fixation-point occurring in an atropinised eye when it makes an effort of accommodation. There can be no "kinæsthetic sensations" since the ciliary muscle is paralysed and no accommodation of the lens is effected. And yet there is an apparent shrinkage of, *e.g.*, a page of print beyond the point of fixation,—fixation-point here meaning the point the subject *intends* to look at though he does not succeed in doing so. (This, by the way, disposes of the suggestion that the micropsia in cases where accommodation actually takes place is due to the fact that the optical image is smaller. This explanation is clearly precluded in the case of the atropinised eye, since the lens has not been accommodated and the image therefore

comes about that when we move our eyes in a normal way[1] voluntarily, objects are perceived at rest, although the retinal images of course move: whereas, if the eye fails to move through paralysis, objects seem to move although the retinal images are stationary. Where again there is movement of the retinal images *without* volition to move the eye, the sensible appearance of movement results. The facts are too complex to reduce to a formula: but, ignoring the complexity, the following formula might be given,—where V = volition, R = movement of retinal image, M = sensible appearance of movement, and S = appearance of objects as stationary:—

$$\begin{aligned} V \textit{ minus } R &= M \\ R \textit{ minus } V &= M \\ V \textit{ plus } R &= S \end{aligned}$$

Dr. Myers suggests in explanation of the facts symbolised in the last of these three formulæ that "in volitional movements of the eyes another factor enters, the act of volition," (*i.e.*, V in the formula), "which, possibly through long experience annihilates the simultaneous effect of retinal sensations of movement" (*i.e.*, R in the formula). The explanation would be unexceptionable, but for the supposition of "sensations of movement" which are annihilated. I can see no valid reason for the commonly made assumption of the existence of primi-

remains unchanged. See *Mind*, XXXI, No. 123, July, 1922, pp. 284-5.) Myers' *Txet-Book of Experimental Psychology*, 2nd Edition, 1911, p. 282.

[1] Unless the movement is abnormal, as in rapid rotation of the eyes, when the sensible appearance of movement in objects asserts itself. This may be regarded as evidence of a primitive retinal sensation of movement showing itself when normal associations are broken through. The argument of this paper is directed just against this view of the facts.

tive sensations which are bare functions of impressions on the sense-organs.[1]

There is an ingrained habit of regarding the sensible appearance as a separable *simulacrum* or *species sensibilis*,—separated from that which is presented and translocated into a subjective sphere, the mind; in which again it maintains an independent existence, separate from the meaning which the mind is then supposed to attach to it *ab extra*. This way of looking at perception already starts with a crude theory of perception, quite uncritically assumed; and only *seems* to be an answer to the problem of knowledge because it has already begged the question in its uncriticised postulates. This is obvious from the concealed metaphors in such terms as "impression" and "image": and it has been pointed out by philosophers often enough. The inevitable outcome of the impressionist account of perception is atomism in psychology, since the bare "impressions," or sensible appearances separated alike from that which appears and from the meaning which in fact makes them what they are, are discontinuous and isolated entities. They are connected through their meaning; and if the meaning is treated as something extrinsic and adventitious they can have no more than an extrinsic and adventitious connection *inter se*. The impressionist psychology is thus limited by its own assumptions to a sort of mental flotsam, the *disjecta membra* of experience, and the inadequacy of the analysis which it offers is not the fault of the experience analysed but of the psychologist's presupposition.

Perhaps there would be a better prospect of understanding experience if we started with another set of presuppositions which appear to be better grounded in experience itself. Two such presuppositions suggest themselves, one rather of a metaphysical and the other of a more innocuous psychological character. The connection between them again would be a

[1] I argued against such primitive sensations in another connection in *Mind*, XXXI, No. 123, July, 1922.

piece of metaphysic on which I do not venture. The first or more metaphysical of these two presuppositions may be stated as follows:—

1. Sensible appearances are not separable from, but are part and parcel with,[1] that which appears. I am not concerned here with this presupposition, beyond putting it forward as a point of view which has *prima facie* as good a claim to be considered as the sensationalist or impressionist presupposition. It admits of a variety of interpretations, and need not commit anyone who adopts it to anything like (for example) Bergson's view of "pure perception."

What I am concerned with is the other or more psychological of the two presuppositions, which might be stated thus:—

2. Sensible appearances are not separable from the meaning which they express. They are not *impressions* having independent subsistence in their own right which acquire a meaning subsequently. They are *expressions* of a meaning, and therefore always presuppose a meaning, which is constitutive of them and not adventitious to them.

How difficult it is for the impressionist psychology to maintain itself in the face of the facts of perception comes out very clearly in James's admirable chapter on the Perception of Space.[2] In a significant passage[3] he begins by stating that "a sensation is the mental affection that follows most immediately upon the stimulation of the sense-tract. Its antecedent is directly physical, no psychic links, no acts of memory, inference, or association, intervening."[4] "If what seems to be a sensation varies

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[1] The phrase is that of the English translation of Bergson's *Matière et Mémoire*, p. 71. Bergson's words are *intuitions immédiates qui coincident au fond avec la realité même*—p. 59.

[2] James, *Principles*, Vol. 2, Chapter 20.

[3] *Op. cit.*, *loc. cit.*, pp. 216—219.

[4] *Every* psychical occurrence has a directly physical antecedent or concomitant—according to the view of the relation of consciousness to the brain which James normally adopts. This criterion of sensation cannot therefore be applied. It would lead to the view that all consciousness is "sensation." But here he is

whilst the process in the sense-organ remains unchanged, the reason is presumably that it is really not a sensation but a higher mental product." His whole chapter is an array of facts which prove that what seems to be a sensation varies whilst the process in the sense-organ remains unchanged: but his conclusion none the less is that these varying psychical processes are "sensational," and he deplores the celebrity obtained by a sentence of Helmholtz's to the effect that "no elements in our perception can be sensational which may be overcome or reversed by factors of demonstrably experimental origin." His own position seems to be that the "higher mental products" are sensational in two senses. In the first place "the same outer objects *feel* different to us according as our brain reacts on them in one way or another by making us perceive them as this or as that sort of thing." In the second place, although identical processes in the sense-organ "give us different perceptions at different times in consequence of different collateral circumstances," we must suppose that there are sensations corresponding to these processes in the sense-organ, which, but for the presence of these collateral circumstances, *would have been felt in their natural purity.* And the means by which this primitive sensation is so transformed by the collateral circumstances is "nothing more nor less than association—the suggestion to the mind of optical objects not actually present but more habitually associated with the collateral circumstances than the sensation which they now displace and being imagined now with a quasi-hallucinatory strength."[1]

I do not think that there is any one who is concerned to deny that objects *feel* different according as they are perceived as different. That is a truism, and only amounts to saying

aiming at differentiating pure sensation from "higher mental products." His meaning appears from the context to be that there *are* elementary physiological processes to which primitive sensations correspond; and that *these* processes are aroused by an external stimulus,

[1] *Op. cit., loc. cit.*, p. 220.

that different sensible appearances are *sensibly* different. And much of what James calls sensationalism is nothing more than this truism: and to that extent we are all sensationalists, and there is no need to argue the case. It is only in the second sense in which he asserts sensationalism that the questionable assumption usually associated with that term comes into prominence. The questionable assumption is that a sensible appearance is essentially a function of a definitely assignable physical process aroused by an external stimulus; and that if under certain conditions that particular physical process seems to be accompanied by a *different* sensible appearance, this must mean that this physical process has aroused another physical process which had this *other* sensible appearance as its function. Thus the rapid successive stimulation of a number of contiguous points on a sensitive surface has as its psychical function the sensible appearance of movement: but owing to collateral circumstances another physical (cerebral) process which has as its function the perception of objects as stationary, is roused to activity, because it is the more habitual associate of these circumstances. James's formula for the "transformation of primitive sensations" is—"the suggestion to the mind of objects not actually present but more habitually associated with the collateral circumstances than the sensation which they now displace." What does this mean, in a concrete case of perception?—James says: "As I look along the dining-table I overlook the fact that the farther plates and glasses *feel* so much smaller than my own, for I *know* that they are all equal in size; and the feeling of them, which is a present sensation, is eclipsed in the glare of the knowledge, which is a merely imagined one."[1] Where are we going to find the "imagined sensation"[2] which is a more habitual associate of the collateral circumstances? How have I formed the habit of "imagining a sensation"

[1] *Loc. cit.*, Vol. 2, p. 180.

[2] An "imagined sensation" is a curious psychological notion. Is it an imagination? Or is it a sensation?

of the farther plates which is sensibly equal to the present sensation of my own plate? James would reply that "out of all the visual magnitudes of each known object we have selected one as the *real* one to think of and degraded all the others to serve as its signs. This 'real' magnitude is that which we get when the object is at the distance most propitious for exact visual discrimination of its details."[1] There is then an "imagined sensation" which is the habitual associate of the collateral circumstance of, *e.g.*, being-a-soup-plate: and this *imagined* sensation of extensity is so habitual an associate that it eclipses in its glare the *actual* "extensity-sensation" which the farther plates give me,—or would give me, but for the eclipse. This may seem plausible at first. But James has just admitted (on the same page) that "there is no reason to suppose that the bignesses of two impressions falling on different regions of the retina are primitively felt to stand in any exact mutual ratio. It is only when the impressions come from the *same object* that we judge[2] their sizes to be the same."[3] This is unquestionably true: and it means that there cannot be found an *absolute* extensity-sensation which might serve as the habitual associate of a set of collateral circumstances. The sensible appearance of magnitude is always a variable, the product of "relative suggestion." So far as the farther plates on the dining-table tend to be perceived as equal to the near ones[4] it will not be because an absolute sense-impression of extensity is the habitual associate of being-a-plate, but because there is a schema of perception at work which

[1] *Loc. cit.*, p. 179.

[2] i.e., *perceive* them as the same. Judging and perceiving are of course distinct functions,—but they are often confused, as here.

[3] He vacillates on this point. On the same page he talks of an "innocence of the eye" which the young draughtsman must recover in order to feel directly "the retinal (*i.e.*, primitively sensible) magnitudes which the different objects in the field of vision subtend."

[4] As a matter of fact perception is contaminated by perspective effects so that the far plates would *not* be perceived as equal. See *Mind*, *loc. cit.*, p. 292.

reduces them to their appropriate dimensions in a perceptual whole. So that the sensible magnitude "suggested" is the *expression* of a meaning, and not a revived sense-*impression* or "imagined sensation."

Sensationalism as a distinctive doctrine is the view that sensible appearances are a fixed function of assignable processes in the end-organs and nervous system. Its opposite is the view that the sensible appearance is a function or expression of meaning. What James sometimes puts forward as sensationalism, *viz.*, that objects perceived as different *feel* different, is not a distinctive doctrine, and is not in question here. What I am concerned with is the position that it is possible to point to sensations which are bare functions of physical processes: this is the real motive and the real significance of sensationalism, which is rather a theory of the relation of the psychical to the physiological than a psychological description of facts. If this theory is to be more than a mere hypothesis it is the business of the sensationalist to point to cases in which a sensible appearance unambiguously presents itself as a fixed function of an assignable physical process. In the attempt to do this sensationalism invariably looks for primitive or "pure" sensations which it regards as fixed functions of more or less elementary physiological processes. There is in fact no way in which he *could* proceed except by looking for relatively isolated physiological processes which have as "concomitant variations" relatively isolated corresponding sensations. It is not necessary that the isolation should be complete, *i.e.*, that he should be able to point to a perfectly "pure" sensation. But he must be able to show that there is a correspondence between *relatively* elementary psychical occurrences and *relatively* isolated physiological processes. If he cannot do this, he will not be able to verify his hypothesis, and will be driven to content himself with a mere assertion that consciousness *as a whole* is parallel or epiphenomenal to brain-process *as a whole*, an assertion so vague and groundless

as to carry no weight at all. My procedure here is in fact based on the postulate that, if it can be shown that there is no evidence for the existence of primitive sensations which are functions of physiological processes, the sensationalist's case goes by the board, and that the way is then clear for another way of looking at perception.

The case for a primitive sensation of movement which is a function of a rapid successive stimulation of contiguous points on a sensitive surface seems to be worth examining, especially as the evidence for such a sensation in this case may seem to be particularly strong. There is in the first place the *biological* importance and presumably primordial character of the perception of objects as moving. The power of movement to arrest attention is a commonplace: and it seems likely that that capacity of detecting movement which is the principal function of the periphery of the developed eye, was the main function of the eye as a whole in its primitive forms; the eye being primitively all periphery, so to speak. And, in the second place, it may seem to be *introspectively* obvious that primitive sensations of movement corresponding to successive stimulation of adjacent portions of the retina can be readily detected by attending to the bare sense-data and ignoring their meaning. If you are moving along a straight road in a vehicle, the trees and the sky that bound your visual field ahead are no doubt normally perceived as stationary, and so is the stretch of road in front of you. But you need only forget the objective framework in which you perceive things normally, and you will find the whole landscape suddenly alive with movement,—the road streaming past you or advancing to meet you, the trees ahead shooting up into the sky, and the sky coming down to meet them.[1] Or if you are in a railway train you can introduce an infinite variety of kaleidoscopic movements into the immobile prospect by the simple device

[1] I have been asked by a child of six why the moon moved along with him as he walked.

of fixating points at different distances from the train. Follow swiftly with your eyes near objects as they stream past, and that near sector of the field of vision comes to rest, while all that is beyond it falls into different rates of movement. Fixate a tree in the middle distance and follow it with the eye, and an utterly different kaleidoscopic effect is produced,—nearer sectors now rushing past you at rates of speed proportionate to their distance from your point of fixation, while sectors beyond your fixation-point move each with its appropriate degree of speed in the direction in which you are going. Follow again an object on the far horizon, and everything between you and it falls into quite a novel movement-pattern.—Can there be any reasonable doubt that all these variations are "primitive retinal sensations of movement" determined by the different rates of speed with which the images of different objects at different distances travel across the retina according as the eye is moving swiftly in following a near object or slowly in following a distant object? Are we not compelled, alike by the *biological* and by the *introspective* argument, to accept the apparently simple and satisfying resolution of the different sensible appearances into primitive retinal sensations or sense-impressions?—I do not think so.

(*a*) As regards the *biological* argument, it seems to follow from the "primitive retinal sensation" theory that every animal as soon as it starts moving its body or its eyes must fall into a state of tense attention to every object alike in its field of vision. For its whole field of vision is now alive with movements each of which *ex hypothesi* gives a primitive sensation of movement of an instinctively and immediately interesting character. This of course is absurd, and does not happen; but it seems to me to follow fairly from the sense-data psychology, ignoring the factor of *meaning* as that psychology does; and to constitute a *reductio ad absurdum* of any argument from biology in favour of a primitive sensation of movement. The fact clearly is that even at the

lower levels of life at which the eye's main function is the sentinel function of detecting movement, the sensible appearance of movement is not reducible to bare sense-impressions, but is already determined by meaning so as to discriminate between movement of *images* over the retina and movement of *objects* (which may or may not be accompanied by retinal image-movement). The animal ignores the former and notices the latter: its vision is already therefore interpretative or expressive of objective conditions. Primitive retinal sensations would not merely be superfluous, but would even be a positive hindrance to a creature. What it needs is sensible appearances *which are meaning-made* and therefore charged with meaning. It must *see* movement when *things* move, and not when retinal images move.

(*b*) The *introspective* argument for sensations of movement amounts to this, that we can see movement whenever there is movement of images across the retina if we attend to these apparent movements and forget the meaning which the primitive sensations have acquired. With reference to this, it seems to me that the facts lend themselves equally well to another interpretation. The very variable nature of the sensible appearances here may be, and, as I think must be, explained as due to the different *meanings* which can be discriminated in the objective conditions, according to the point of reference which may be taken. If you are walking or moving in a vehicle going at a normal pace your own body is normally perceived as moving, and the surrounding objects are consequently seen at rest. But you can, if you will, make your own body the fixed point of reference; and you then perceive the change in position of other objects with reference to it. This *relative* change of position of other bodies is as good an objective fact as the movement of your own body is. In perceiving objects as changing position with reference to your body, you are perceiving an *external reality*,—not a movement that is taking place on

your retina, nor a corresponding subjective modification "in the mind." There is no reason why these relative movements and parallactic displacements should be treated as mere subjective appearances, and relegated to the mind (or to the retina), as "sensations," on the ground that they have no physical existence "outside the mind." They *have* physical existence; and it is an objective fact that, when I walk a few steps across the room, a line which might previously have been drawn through the door to a certain tree in the garden, will no longer lie through that door in order to join my body to the tree (if it is to remain straight), but will now pass through a totally different series of points. When I see the tree moving past the door with me as I move, I am seeing what actually takes place: and there is no reason why the facts perceived in this case should be treated as in any special sense "pure sensations." The sensible appearances of relative displacement, like those sensible appearances of size and shape which we call perspective effects, although not normally noticed, are none the less expressions of objective relations. Our actual percept may perhaps be a *tertium quid*, a compromise between "real" position and movement and "relative" displacement. Both meanings may find partial expression in the sensible appearance,—as certainly happens in the case of the sensible appearance of size-distance,[1]—each meaning being so to speak contaminated by the influence of the other. There is, in fact, probably always in the sensible appearance something of that "overdetermination" which is a prominent feature in dream-imagery, and in virtue of which the appearance may mean two things at once. In this particular case of the perception of position and movement the two meanings that are expressed are not incompatible as objective facts; for the road, *e.g.*, does go past me as I go along the

[1] See the article previously referred to, in *Mind*, July, 1922, p. 292.

road,—and there seems to be no reason why I should not in some degree see both things at once.

The movement of images across the retina is no doubt one of the conditions of the visual appearance of movement. But there are numerous examples, besides the one which I took as my text,[1] in which sensible appearance of displacement is found even in the absence of this condition. In the first place it is to be noticed that the movement of images over the retina which is normally a necessary condition of perception of movement, is not necessarily, nor even perhaps normally, movement of the image corresponding to movement of the object which is perceived as moving. Quite ordinarily it is the images corresponding to the surrounding objects, *i.e.*, the background, that move over the retina, while the object which is perceived as moving has its image stationary on the retina. The normal condition of the perception of movement is *any* sort of movement of images over the retina, producing *relative* displacement of images or kaleidoscopic change: and there is no fixed relation between movement of a particular image and perception of the *corresponding* object as moving. This comes out very clearly in certain illusions of movement of which the familiar example is the irresistible feeling that the stationary train in which you are sitting is itself moving when another train goes past the window out of which you are looking. The principle of these illusions (which are distinct from those which depend on unconscious eye-movement, such as the "giddy" appearances of movement following upon rotation of the body) is thus stated by Myers: "When part of the visual field is moving it tends to induce an apparent contrary movement in surrounding stationary parts of the field. Generally the larger part of the field is interpreted as being at rest, while movement is ascribed to the smaller parts; as occurs in the apparent movement of the

[1] In the first paragraph, p. 187, *supra*.

moon when actually clouds are being blown across it." Facts of this type are among the arguments adduced by James as proving that movement is a primitive form of sensibility. "These illusions, according to Vierordt, are survivals of a primitive form of perception when motion was felt as such, but ascribed to the content of consciousness, and not yet distinguished as belonging to one of its parts."[1] But the facts seem to be against rather than in favour of James's conclusion. And to talk of ascribing motion to the "contents of consciousness" is grotesque.

Some of the facts are explained by James[2] on the physiological principle that "processes in the visual apparatus propagate themselves laterally,"—the principle which is also used to explain the phenomena of colour-contrast. The familiar type of these facts is the experience of seeing the ground on which you are standing appear to move in the contrary direction while you are watching a stream flowing past below you,—an illusion which can be produced under experimental conditions. Myers, however, classes these facts with those just noted, and there does not seem to be any need to invoke James's physiological principle.

There are some curious and unexplained facts mentioned by Myers,—the so-called Autokinetic Sensations.[3] A stationary point of light in a dark room appears to move, in some cases, *independently of eye-movement.* Thus if the attention is directed downwards the light appears to move *downwards,*—which seems to prove that eye-movement was not the cause of the apparent movement, for had it been so the light would have moved *upwards.* Dr. Myers thinks that "what changes under such conditions is not the judgment of the position of the object in the visual field but the judgment of the position

[1] James, *Principles*, II, p. 172.

[2] *Op. cit.*, Vol. II, p. 245.

[3] Myers, *Exp. Psych.*, p. 230.

of external space relatively to ourselves." He suggests that it is "the visual schema of our spatial environment which, in some of us at least, tends spontaneously to alter..." "The probability is that we come to construct for ourselves various 'schemata,' as Head calls them, *i.e.*, systems of unconscious dispositions, upon which *inter alia* is based our awareness of the spatial relations of the external world to ourselves...." Is it not possible that the explanation of that curiously baffling experience which we have when we wake at night and completely fail to orient ourselves in the dark room, implies some such spontaneous alteration of our spatial schema? In these circumstances, even when we succeed in making out the outline of a window, we still fail to realise how it is related to our position, and feel that it ought to be somewhere else.

The sense-impressionist is obliged to treat such cases as abnormal and exceptional. The impressions which are the functions of the existing processes are somehow eclipsed by "an imagined sensation," owing to collateral circumstances, and this imagined sensation somehow acquires "quasi-hallucinatory intensity." But it seems to me that these cases are not abnormal, nor do they require any *ad hoc* interpretation; they are rather "glaring instances" of ordinary perception, instances in which its true nature (which has been obscured by an *a priori* parallelistic theory of perception) stands clearly revealed. If in the light of these glaring instances we disabuse our minds of the parallelist prejudice I think it will be found that all cases of perception find their explanation in a sense-*expression* (as opposed to a sense-*impression*) account of the sensible appearance. It is only the ingrained parallelist way of thinking that leads us to speak of sense-*impressions* and to suppose that, as the physical object somehow produces a copy of itself on the physical organ of sense, so this physical image or impression somehow duplicates itself in a psychical edition. I admit that often things happen *as if* this were the

case: but, apart from the fundamental unintelligibility of the parallelist standpoint, I believe that there are in all departments of perception glaring instances in which the real nature of perception shows itself unambiguously, and in which the parallelist or sense-impressionist account conspicuously breaks down.

Parallelism only seems to give a plausible account of perception because it takes a world of sensible realities already for granted; which indeed is in itself an unobjectionable procedure, for there is no way of arriving at a real world unless you start with one: but it becomes objectionable if the initial assumption of the world-as-known is then forgotten, and a pretence is made of answering the question—How, *given nothing at all*, does perception arise? That is an unanswerable question; but it is the characteristic paralogism of a sense-data psychology to suppose that it is answering this question. The only reasonable question is—How, given the world-as-known, does any particular percipient's perception of it arise? The sense-impressionist's answer is that, in the particular case of the perception of movement, for example, movement is perceived because the stimulus travels over a sensitive surface, *i.e.*, adjacent points on a sensitive surface are stimulated in rapid succession. The implicit assumption is probably made that like cause has like effect, so that a *moving* point of stimulation naturally generates a "sensation" of movement. There is no ground for the assumption: and even if there were, it is a mere figure to speak of a *moving* point of stimulation: the literal fact being that a *series* of points are stimulated. The stimulation of a series of points, if like generates like, would generate a succession of sensations, and not a sensation of movement. Of course another factor comes in in successive stimulation, *viz.*, the overlapping of the successive effects of successive stimulation, so that the effects of the stimulation of points A, B, and C, still persist at the moment when point D is stimulated. But even so there is

no likeness between movement and the simultaneity of dying and dawning phases of stimulation in adjacent points of a sensitive surface. In fact the sensible appearance under such conditions is *not* one of movement but of a continuous line, such as the band of colour seen on a rotating disk bearing a sector of colour. The principle of like generating like if it were explicitly formulated (I do not think that it ever is so formulated) would not bear analysis.

The essential condition for my *seeing* movement is that I *know* or think that I know, that there is a moving object there. I do not know that there is movement because I see it: on the contrary, I see the movement because I know that it is there. This is a paradoxical way of expressing the facts, however; for it seems to imply that the knowing is separable from the seeing, the meaning from the sensible appearance which expresses it: and the truth which requires to be emphasised is just that sensible appearance and meaning are inseparable.

There is a strong prepossession in favour of treating the sensible appearance as something quite separate and distinct from its meaning. I think that the ground of this prepossession is the distinction between what is and what is not actually "present to the senses." In the case of the book lying on my table, for example, it seems obvious that the upper cover, the top edge, and the back, are now presented to me in a way in which the bottom and front edges and the lower cover are *not* presented: and that in general the outside of a thing is presented, whilst the inside is only ideally represented. Certainly any view of perception which ignored this distinction would stand self-condemned. Perception is of course limited by physical conditions, and to know that a thing has an inside is obviously not the same as seeing inside it. All that is meant by saying that the sensible appearance is inseparable from its meaning is that (in the case just taken, for example) the outside of the thing presents itself *as such* only because

we know that it has an inside; and that you can never explain the sensible appearance of what is "present to sense" as a function of the physical impressions on the sense-organ.

THE REALIST'S CONCEPTION OF IDEALISM.

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Transcendentalism.—It has been aptly said that the terms realism and idealism are "traditional battle-cries and watchwords rather than names of precision."[1] This is only natural. Every thinker has, of necessity, to accept certain facts as given, and no amount of theorizing is equal to the task of driving them out of existence. If then the distinction between idealism and realism is, as is ordinarily supposed, to rest on the acceptance by the latter of facts denied by the former, then the sooner we cease to talk of the distinction the better, for no one who has ever approached the facts of experience with an appreciative outlook could reduce them to nothing. So, on the one hand, Berkeley's system has been supposed to be thoroughly realistic in its intention[2] and, on the other hand, it has been said that Reid's realism "might pass into the most extreme idealism."[3] To realise the lack of precision and the difficulties in the conception of this distinction, one need only look at the different *fundamenta divisionis* that have been proposed by different thinkers. Realism, it is sometimes said, must insist on the independence of the objects of experience in general over against the idealistic contention of their dependence on the experiencing mind. More frequently, the distinction is supposed to rest on a more restricted basis, namely, the relation between

[1] Dr. Bosanquet: *Contemporary Philosophy*, Preface.

[2] See Prof. Laird's article in *Mind*, 1916.

[3] Dr. Bosanquet: *The Essentials of Logic*, p. 10.

the perceiving mind and the external world revealed in perception. It is this narrower problem which generally comes to the foreground in controversies, and then realism is thought to consist in the assertion that the external world which is before the mind in perception is not dependent on the perceiving subject. This general position again is accepted by different realists with different degrees of qualification, some insisting on the independence of the external world in its existence as well as qualities, others making the qualities dependent on the perceptual context. As thus defined, it is difficult to distinguish realism from that type of idealism which is represented, say, by T. H. Green who urges unambiguously that "the fact that there is a real external world...is one which no philosophy disputes."[1] The demarcation line is sometimes drawn at a different place, and the centre of emphasis is shifted from the external world to the conception of time. Realism maintains, while idealism denies, that the universe as a whole is in time, evolution or change; yet thinkers like Croce, Gentile and Ward are claimed to be idealists. Finally, the term idealism has been made to cover "all those philosophies which agree in maintaining that spiritual values have a determining voice in the ordering of the universe";[2] yet Prof. Alexander is widely known as a prominent realist of our time. We are not substantially helped out of this confusion by Mr. J. Laird when he defines realism as "a theory of knowledge whose essence is to supply a complete phenomenology of knowing and of things known [in a] peculiar and distinctive way";[3] and the confusion is still more increased when it is claimed that the main assumption of realism is that things can be known as they really are, that "the object of true knowledge is in a certain sense independent of our knowing of it,...the fact of being known

[1] *Works*, Vol. I, p. 376.

[2] N. K. Smith: *Prolegomene to an Idealistic Theory of Knowledge*, p. 1.

[3] *A Study in Realism*, p. 8.

does not imply any effect upon the character or existence of thing which is known.... All idealists, in spite of their differences dispute this independence of the objects of knowledge."[1] That our knowledge does not falsify reality and that the object is independent of the act of knowing in a certain sense, are not disputed by the idealist. Every idealist who knows his business must admit that, "when I use the word 'red,' I mean a colour ...which I think of as not dependent either for being or for quality on my happening to know it";[2] on the contrary, "the sun means the sun; and whatever that may be, it is not anything *merely* in my mind,......not a psychical fact in my individual history."[3]

It is amply evident from the above that all attempts at defining the contrast between realism and idealism by reference to the facts supposed to be accepted by the former and rejected by the latter must be futile. And in so far as the reality of the external world is concerned, even Berkeley, while arguing for the mind-dependent character of the material world, maintained emphatically that nothing which was considered real by common sense had been banished by his system. To appreciate the real contrast then, we may revert once more to Green. In continuing the thought, to which reference has been made above, he observes that no philosophy disputes the fact that there is a real external world "of which through feeling we have a determinate experience...The idealist merely asks for a further analysis of a fact which he finds so far from simple."[4] That is, while the realist takes the facts "at their face-value," the idealist asks for the conditions involved in the factual nature of the so-called facts. If this is made the criterion of idealism, then we must look to Kant rather than Berkeley for a true lesson in idealism; for it was Kant who for the first time raised, and

[1] *Ibid.*, p. 14.

[2] Bosanquet: *Logic*, Vol. I, p. 17.

[3] *Ibid.*, p. 73.

[4] *Ibid.*, p. 376.

attempted a solution of, the question :—how is nature possible? It will be unprofitabte at this place to hazard any opinion on the success or failure of Kant's task—a task which is universally admitted to be extremely difficult. But what can be said positively is that it was he who first realised the importance of striking this "hitherto untravelled route" and brought philosophy to transcendental investigations. This Fichte considered to be the epoch-making achievement of Kant. His works have been compared to a bridge by which we pass from the spirit of the eighteenth to that of the nineteenth century, and the great change which this latter brought into the intellectual outlook of man has been aptly described as the "substitution of the idea of organic unity and development for the idea of the mechanical combination of reciprocally external elements."[1] In the thinkers of the Enlightenment the desire to be clear at any cost, grew into such a master-passion that they could not admit the truth of anything except what would stand out with clear-cut features and hard immutable outlines, the consequence being a wide-spread disorganization in the different departments of life. This led Kant to ask for a "further analysis" of the so-called facts. So, if we are to retain the terms Idealism and Realism, we must give up the old method of contrasting them, and define Realism as the habit of accepting the facts as out there unconditioned and absolute. Idealism, on the contrary, insists on the conditioned nature of the ordinary facts of experience and holds that apart from their conditions the so-called facts are reduced to non-entities. As thus defined, Kant in his reply to Hume, undermined the basis of realism, and laid the foundation of a system of idealism which is as opposed to subjective idealism as any system of realism has ever been.

The Cognitive Relation.—We have deliberately omitted so far the consideration of an eminently suggestive definition of realism, for it raises an issue of really vital importance—an issue the right understanding of which goes

[1] E. Caird: *The Critical Philosophy of Kant*, p. 46.

a great way to mould one's final view of the universe. In defining the general characteristic of realism, Prof. Alexander maintains that mind has no privileged place in the democracy of things, "in respect of being or reality, all existences are on an equal footing......This attitude of mind imposed by the empirical method is and may rightly be called in philosophy the attitude of realism."[1] Judged by this standard, Locke together with his followers should, we believe, be considered as realists. That the finite mind is only one object among others distinguished from them by the attribute of thought was a belief which pervaded Locke's investigations from the start to finish. Now this belief, or rather attitude, which is called realistic here, has been elsewhere[2] considered as the attitude of psychology, and Prof. Alexander thinks that the study of mind in metaphysics "must be borrowing a page from psychology."[3] This is evidently a bold step, for even William James, the modern protagonist of this attitude, did not think it justifiable except from the standpoint of psychology, thus suggesting that the metaphysics of mind could not be coterminous with the psychology of mind.[4]

This levelling down of mind to the status of other things is carried further by the American realists. Thus Mr. E. B. Holt considers the mind to be the cross-section of the environment, and in this sense mind or consciousness belongs to the totality of objects. All objects are portions of a mass of object which the neural response selects from the world, and these objects are not simply the so-called physical objects, but sensations and memories, thoughts and volitions, have as much claim to the name as the rest. Here the realistic attitude leads to pure objectivism, and the introspective psychology is

[1] *Space, Time and Deity*, Vol. I, p. 6.

[2] Dr. E. Caird: *Critical Philosophy*, Vol. I, p. 11.

[3] *Ibid.*, p. 9.

[4] *Principles of Psychology*, Vol. I, p. 183.

reduced to 'behaviourism.' Mind has no privileged place in the democracy of things, because mind in the traditional sense is an outworn superstition, while in the realistic sense it belongs to the totality of objects. Here, in this materialism of the American realists, we find an illustration of the *reductio ad absurdum* of the psychological or empirical method which is not less instructive than what was illustrated in the course of pre-Kantian empiricism. Following the introspective method which Locke introduced into epistemology, Hume reduced mind into a bundle of perceptions which led to the denial of mind not only in the sense of a substance persisting through the continued flux of conscious states, but in the sense of a thinking subject too. But the modern feat of reducing the mental to terms of the physical organism was unknown to him.

It has been pointed out by the critics of this cross-section view of mind that it does not explain one vital fact in the cognitive relation. The crucial error of New Realism, according to Mr. L. A. Reid, is that it has no way to the admission that "*I* am in *thee* and *thou* in *me*."[1] Similarly, Prof. Alexander, while admitting the simplicity of the theory—a theory to which he finds himself "perpetually being drawn back and persuaded to adopt"—admits that it "fails to account for a vital feature in the cognitive situation, as we experience it, namely, that in being aware of the fire, the fire is before *me*, or it is *I* who see it, or it is in a sense *my* fire."[2] This is really the vital feature which cannot be accounted for by any theory which is realistic in the above sense. It is not only the theory of search-light, but every theory of mind which adopts the abstract method of empirical psychology in its analysis of the cognitive relation must fail to offer an ultimate explanation of the fact that a common world is revealed to a plurality of minds. If idealism rejects the realistic analysis of experience, the ground of the rejection is not to be

[1] *Knowledge and Truth*, p. 50.
[2] *Ibid.*, p. 111.

found in the so-called idealistic prejudice that mind is somehow superior to all other existences; but it is rejected because its analysis is inadequate and superficial. The ultimate test of a sound philosophy, we are persuaded to believe, is its capacity to explain how the *fire* is before *me.* The fire is an object having a unity and permanence, as against the multiplicity and transitoriness of the cognitive acts through which it is grasped; it has its 'date' and position, a past and a future; it, together with other objects, constitutes parts of one world; it reveals itself to many minds, each claiming its own experience as *mine*, while referring it to one identical object. These are some of the aspects of experience which a metaphysical analysis must not ignore.

That the behaviouristic analysis of the cognitive relation is utterly inadequate, is clearly seen by Prof. Alexander. But is it not the legitimate conclusion which must be ultimately drawn whenever experience is analysed by means of a false method? His great merit no doubt consists in realising that the 'mental' cannot be put in terms of the 'non-mental'; yet he is essentially on the verge of the dangerous ditch from which he is trying to keep himself off, so long as cognition is taken to be a particular instance of the general relation of compresence. To behaviourism there is an easy, and perhaps an inevitable transition from the assertions that "the behaviour of finites to one another in this relation of compresence is determined by the character of the finites. The plant lives, grows, and breathes, and twines around a stick. The material body resists, or falls, or sounds when struck, or emits light when touched by the sun. The mind knows."[1] The cognitive situation remains substantially the same, the mind on the one side, and the objects on the other entering into a temporary mechanical relation. While this is not challenged, it is immaterial whether we consider the knowing mind as a qualitatively distinct kind of physical thing possessing a

[1] *Ibid.*, Vol. II, p. 81.

unique type of response, or the object as a kind of existence which is in some sense mental either as a 'state of consciousness' or a mere 'idea' in the mind. That is, the problem of knowledge is unaffected whether we are landed in an unqualified objectivism or an unqualified subjectivism. A few remarks of Lord Haldane's are so pertinent here that we cannot help quoting them at some length: "We have ever to avoid the stereotyping of a general principle into the form of an image......Two of the most dangerous kinds of these have their origin in an unduly loose use of the conceptions of cause and of substance......The full meaning of what we experience may be something very different from the relation of cause or of thing with its properties that we assume ourselves to observe. The self-determining operation of an end, for example, is not causal in the ordinary sense. The cause does not here pass over into the effect as a new aspect of the originating energy....Nor is the relation of mind to its manifestations that of a substance to its accidents....Knowledge is the highest category, and it is not a merely meticulous criticism of expressions. The whole of the Berkeleian theory, and the essence of what is now called Mentalism, seem to depend on mind being regarded as a substance, and knowledge as an activity or property of that substance. But the New Realists generally appear to make the same sort of assumption as the Mentalists about the adequacy of the category of substance, for they treat knowledge as the causal result of the operation of one set of things in the external world on another set of things there, the nervous system, imaged as compresent with them in a fundamentally real time and space....Most of the controversy between Subjective Idealism and Realism seems to arise out of the metaphorical view of the human mind as something that looks out through the windows of the senses. The Subjective Idealists say that beyond the activity of the mind in this outlook there lies nothing, and that what is real is just the mind and this activity. The Realists...

discover knowledge to be just an additional external relation, superinduced on that in which my arm-chair, for example, stands to the fire which I see near me while I am writing, and consisting in a special kind of causal operation of that fire upon my nervous system."[1] To understand the origin of this mistaken conception of the subject-object relation, it is necessary to consider some of the difficulties besetting the problem of external perception.

What is an Idea?—How we perceive external objects, Reid points out,[2] is a difficult problem with many ancient and modern philosophers. Plato's illustration of men bound to a dark subterraneous cave and knowing only the shadows of reality gave rise to this problem. These shadows of Plato represent the species and phantasms of the Peripatetic school, and the ideas and impressions of modern philosophers. Descartes, while rejecting only a part of the Peripatetic system—namely, that images come from the external objects, adopted the other part—that the external object itself is not perceived. For this adoption, however, Reid contends, Descartes does not give reasons. All philosophers from Plato to Hume agree that we do not perceive external objects immediately. It is owing to this "original defect" that the "ideal system" leads to scepticism. Our analysis, therefore, must discard that doctrine, and should be inspired by the belief that our knowledge involves from the very beginning certain "judgments of nature—judgments not got by comparing ideas and perceiving agreements and disagreements, but immediately inspired by our constitution." This, as explained by Prof. A. Seth, means that "we do not have sensation first, and refer them afterwards to a subject and an object; our first having of a sensation is at the same time

[1] An article in the *Proceedings of the British Academy*, Vol. IX. See Green's explanation of Locke's confusions as due to the misapplication of the conceptions of cause and substance—*Works*, Vol. I, p. 109.

[2] *Works*, Hamilton's edition, Vol. I, p. 262.

the knowledge of a present object and of that object as somehow related to me."[1]

It is not our present purpose to enquire how far Reid is justified in assimilating Plato's view on our knowledge of the external world to that of Hume, or why Kant's speculations about the external world did not lead to scepticism in spite of the fact that he never questioned, as has been sometimes maintained,[2] the fundamental assumption of the "ideal system." All we can do here is simply to remember that it is possible in the one case to think that Plato "does not volatilise, so to speak, our world of facts and externality, but accepting for it all that it claims of existence and reality, then passes on to interpret its conditions, and assigns its significance more profoundly."[3] And in the other case, it is equally possible so to interpret Kant's thoughts as to distinguish them from the false view of idealism according to which the external world is merely the creation of our own minds—"a doctrine expressly rejected by Kant and which has had no place since his time in any idealism that knows what it is about."[4] It must be however admitted that the idealistic contention that the world is my idea is extremely liable to misinterpretation, owing to the association the term "idea" has acquired in our minds. By an idea we ordinarily mean a mental picture, a representation or copy of a thing outside the mind. As thus understood, it is manifestly absurd to reduce the outside thing to the idea, we should rather think the thing to be the antecedent condition of the idea. We may go further and admit that the difficulty in this case arises to a large extent from the conditions of our discursive thought which understands by division, and defines by exclusion. Owing to this dichotomous intellect we have to make our notion of 'idea'

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[1] *Scottish Philosophy*, p. 78.

[2] Prof. A. Seth: *Scottish Philosophy*, p. 150.

[3] Dr. Bosanquet: *Contemporary Philosophy*, p. 2.

[4] Green: *Works*, Vol. I, p. 386.

definite only by contrasting it with what is *not* an idea; and evidently the most natural candidate for such a contrast is the ideatum or the thing which the idea is said to represent. That is, the ideas have for adult consciousness a reference beyond themselves to something non-mental in contradistinction from which they are defined. Hence the realist has always the advantage of this popular distinction whenever the idealist speaks of the world as my idea; and in spite of the indignant protest of the latter that he should be so grossly misunderstood, the former continues to consider idealism to be a doctrine which, somehow or other, attempts to spin the world of reality out of psychical existences. Without essaying the difficult task of presenting idealistic contentions in a way which will not be open to misinterpretation, let us turn to the advocates of the "ideal system" and see why they used the term 'idea' for the object of immediate experience. And to make this point clear we should turn to the system of Hume, not only because he is the most consistent of the advocates of what Reid calls the ideal system, but also because Hume's scepticism is supposed to be the legitimate outcome of the doctrine of ideas.

The immediate object of knowledge Hume calls perception which he divides into impressions and ideas, and the difference between these, he says, consists in the degrees of force and liveliness with which they strike upon the mind. Impressions are those perceptions which "enter with most force and violence," and in point of time they are prior to the ideas. Impressions again are divided into those of sensation and those of reflection, but the second is derived in a great measure from our ideas, and so the impression of reflection are "posterior to those of sensations and derived from them." Hence the simple impressions of sensation are the ultimate material of all knowledge. In illustration of these impressions of sensation and their relation to ideas Hume says that "to give a child an idea of scarlet or orange, of sweet or bitter, I present the

objects, or in other words, convey to him these impressions," but "wherever, by an accident, the faculties which give rise to any impressions are obstructed in their operations, as when one is born blind or deaf, not only the impressions are lost, but also their correspondent ideas." The characteristics of the impressions of sensation Hume states more precisely in the famous section of the Treatise on Scepticism with regard to the senses. He seeks to examine here the belief in the *continued* existence of objects even when they are not present to the senses, and the belief in the existence of objects *distinct* from the mind; and his conclusion is that the opinion of a continued and of a distinct existence never arises from the senses or the reason but from imagination. Everything, he says, "which appears to the mind is nothing but a perception and is interrupted and dependent on the mind." All impressions are "perishing existences." Certain impressions are involuntary, *e.g.*, our pains and pleasures, and the impressions of figure and extension. Those impressions "which we regard as fleeting and perishing have also a certain coherence or regularity in their appearances." Our broken and interrupted perceptions resemble each other. "All our perceptions are dependent on our organs and the disposition of our nerves and animal spirits," *e.g.*, "when we press one eye with a finger, we immediately perceive all the objects to become double, and one half of them to be removed from their common and natural position....This opinion is confirmed by the seeming increase and diminution of objects according to their distance; by the apparent alteration in their figure; by the changes in their colour and other qualities, from our sickness and distempers, and by an infinite number of other experiments of the same kind." "We clearly perceive the dependence and interruption of our perceptions." With regard to the characteristic of dependence, Hume says later that there are certain "variations of the impressions"; but "when different impressions of the same sense arise from any

object, every one of these impressions has not a resembling quality existent in the object. For as the same object cannot, at the same time, be endowed with different qualities of the same sense, and as the same quality cannot resemble impressions entirely different; it evidently follows, that many of our impressions have no external model or archetype." But "when we talk of real distinct existences...we think an object has a sufficient reality when its being is uninterrupted and independent of the incessant revolutions, which we are conscious of in ourselves." "I am naturally led to regard the world as something real and durable, and as preserving its existence, even when it is no longer present to my perceptions," because "this supposition" is the "only one upon which I can reconcile these contradictions of observations."

One point in this extraordinarily suggestive psychological analysis of external perception needs special emphasis. On the one hand, Hume characterises the immediate object of perception as transient, variable and contradictory. On the other hand, he describes them as given, though dependent on our psycho-physical conditions. Hume appears to have received from his critics less than justice in both these respects. The realists point out that the immediate objects of our perceptual knowledge are erroneously called ideas which shut us off from an immediate perception of an external world. The idealists complain that he ascribes to the mere sensation a factual existence which it cannot have except through the works of thought. To begin with the former, the original assumption of the "ideal system" appears to be based on a profound logical insight. The world of experience is for the adult mind split up into a multiplicity of worlds with varying grades of reality; we habitually make the experiences of waking consciousness the standard of reality, and then seek to explain dreams by reference to that standard. Within the waking experiences again it is customary to distinguish between experiences which are real and those that are illusory or abnormal.

Descartes, determined to assume nothing which cannot arrest doubt, discovers that these divisions which we make within experience are due to reflections the validity of which can be doubted and so stands in need of proof. The immediate objects presented to us in dreams, illusions and the so-called real experience are perfectly similar. Something is apprehended, the subject not yet judging what that something is—this is immediate experience. The starting point of knowledge then is furnished by given facts devoid of all interpretations. This is the truth which the 'ideal system' seeks to convey by its original assumption. It is of course another question how far its advocates have consistently adhered to the standpoint of immediate experience. In fact, it is the very simplicity of the data which makes it a difficult task to essay a description without clothing them with the categories of interpretation. This difficulty has led many to deny their existence altogether. There is, however, a more serious difficulty, which has prevented the critics of the ideal system from recognising its true merits. Most of the philosophers from Descartes onward, in their description of the data, have either consciously or unconsciously introduced concepts of doubtful application, *e.g.*, 'mental,' 'state of consciousness,' 'mind-dependent,' etc. Thus their description becomes a curious mixture of logical sagacity and philosophical confusion. "Ideas" are said to be whatever we are conscious or percipient of, when viewed without respect to truth or falsehood; and in this respect they are rightly described as transient existences. But they are further classified as mental or mind-dependent. That they are presentations is beyond doubt, and this must be admitted by realists and idealists alike. As so regarded they have all the characteristics by which the realists describe the sense-data. It is said[1] that the "particular sense-data here and now cannot be doubted. Taken thus abstractly, they assert nothing, they mean nothing. They simply *are*....They are, occur, are 'had' or experienced.

[1] Hoernlé: *Studies in Contemporary Metaphysics*, p. 76.

In this sense, of course, their 'reality' is not in debate. But as soon as they are taken to mean something, are classified in some way......they are caught up in a network of theory, and their reality in *this* sense is at once open to doubt, but open also to confirmation." So, the really debatable part of the "theory of ideas" is how far the ideas as the immediate sensible objects are mental existences. To call them mental, to start with, is apparently to commit the "psychologist's fallacy." But to deny their existence altogether is to commit what may be called the "epistemologist's fallacy." Facts in order to be interpreted must be first apprehended as given, however short the interval may be between these two phases of knowledge. It is needless to labour this point—a point which has been pressed with relentless acuteness by the critics of idealism.[1] Kant's "natura materialiter spectata" can no more be reduced to mere relations than the ideas and perceptions of pre-Kantian empiricism or the sense-data of contemporary philosophy.[2] If the post-Kantian identification of form and content is interpreted as a polemic against the distinction of the given facts from their interpretations, we must reply in Kant's words that our understanding is not intuitive. The recognition of the immediate objects of perception then, we claim, is the true merit of what is generally known as subjective idealism. In so far as Hume's opponents have failed to do justice to this aspect of his teachings, the real difficulties of external perception are simply flung to the winds. Yet, the superiority of Reid has been often supposed to lie in rejecting simple apprehension in favour of apprehension accompanied

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[1] *E.g.*, by Prof. A. Seth in his *Hegelianism and Personality*, pp. 79—83. It is however claimed that even Hegel did not mean to reduce the matter of intuition to pure thought—McTaggart: *Hegelian Dialectic*, second edition, p. 18 n.

[2] This however does not mean that we can *know* these ideas, in the strict sense of the term 'knowing,' without and apart from all relations. We can surely feel the tooth-ache without being dentists, but to know the feeling in the totality of its conditions under which alone it is real, is entirely different from knowledge in the way of feeling.

with belief and knowledge, as a true description of the beginning of experience.[1] This theory, it must be admitted, has an appearance of simplicity by which it readily recommends itself to our ordinary ways of thinking. But appearances may be deceptive. This much at least is unquestionably true that all the theories about primitive experience are necessarily of a conjectural character. Consequently, to those who think that the only remedy for subjective idealism is the recognition of the belief in external existence from the start of experience, we must point out that this method of dealing with subjective idealism cannot be ultimately effective. As an account of the psychological genesis of our belief in the external world, it is purely conjectural; and secondly, even granting the truth of this psychological account, it does not solve the problem of validity. All our beliefs have their psychological conditions, but in spite of their necessity as events in the history of the individual's mind, many of them are false, and are in fact found to be mere "fictions of imagination." Even if we grant that Hume was wrong in deriving the fiction of external existence from the constancy and coherence of the perceptions, instead of recognizing its presence from the start, it must make us wonder why this primitive fiction is not rejected by us with the growth of experience in view of the fact that in dreams and hallucinations this fiction unmistakably betrays its fictitious character. We are, therefore, unable to follow those psychologists who, like Mr. Stout, insist that presentations always involve the thought of that which is not itself a presentation. We are obliged, in view of the limited space at our disposal, to put off the consideration of the question how far Kant can be bracketed with Reid[2] in this respect. The distinction between the question of genesis from that of validity, as is well-known, is one of the most reiterated warnings of his criticism and it would be surely strange if he should weaken the

[1] *Cf.* A. Seth: *Scottish Philosophy*, p. 78.
[2] *Ibid.*, p. 88.

force of his transcendental deduction in favour of an extremely questionable theory of external perception.

The philosophical confusion mentioned above, which is mixed up with the logical sagacity in Hume's analysis, arises from an apparently ambiguous way in which the advocates of the "ideal system" use the words "idea," "perception," etc. On the one hand, they are called transient existences, but, on the other hand, they are frequently described as mental or mind-dependent appearances. But why should they be called mental at all? It is apparently unquestionable that the bare knowledge of their existence need not necessarily include the belief that they are mental. It has been, however, pointed out[1] that this question drives the subjective idealist to a quandary; for "he can only prove things perceived to be subjective by proving them to be externally related to objects as their mechanical effects, and yet this can only be done by simultaneously interpreting the things perceived in a manner which the realist standpoint can alone justify." This contention may in fact be substantiated by numerous quotations from their works. It is specially true of Locke that his theory of sensation is "chiefly influenced by the physiological standpoint." And it is also true that Hume frequently talks of external objects "becoming known to us only by those perceptions they occasion." But they do not, as he himself points out, represent his true views; for "when the mind looks further than what immediately appears to it, its conclusions can never be put to the account of the senses," nor is it possible that our reason "ever should, upon any supposition, give us assurance of the continued and distinct existence of body." In fact, neither Locke nor Hume could seriously accept the physiological theory of sensation.[2] Their problem being to

[1] N. K. Smith: *Prolegomena*, p. 53. *Cf.* also his *Commentary to Kant*, p. 587.

[2] The problems arising out of Locke's 'new way of ideas' could not be solved by physiology. No critic who does not see this is in a

explain how our belief in the external thing grows out of the immediately given sense-data, it was not open to them to start with that belief and explain the sense-data as the effect of external things. So it has been emphatically maintained[1] that in this respect, "Hume is as much a Berkeleian as Berkeley himself, and they effectually exclude any reference to body from those original impressions, by reference to which all other modes of consciousness are to be explained." It must be however admitted that the real problem raised by Locke is never kept clear of the confusion arising from the physiological theory. Even Descartes, though attempting to approach all varieties of experience with a perfectly impartial attitude, is, when the problem of external perception is at issue, chiefly influenced by physiological considerations. And in so far as this is the case, Mr. Smith's observations are entirely justified. But what we contend for is that their confusions on this head were due to the difficulty of keeping consistently to the standpoint of immediate experience to which it was their merit to draw the attention of the thinkers for the first time. It is only when we come to Hume that we see a genuine attempt made to keep clear of that confusion ; and so Hume, in spite of his occasional lapses, detects that "properly speaking it is not our body we perceive when we regard our limbs and members, but certain impressions which enter by the senses." More precisely he ought to say "impressions which are ordinarily supposed to enter by the senses."

position to do justice to the subjective idealists. See Green's *Introduction*, sec. 198 ; also Adamson on the ambiguity of the term 'idea'—*Modern Philosophy*, p. 113. Indeed the mistake of confusing these two standpoints has been very common among the exponents and the critics of the theory of ideas. *Cf.* Broad : *Scientific Thought*, pp. 256, 510 ; and Bergson : *Mind Energy*, p. 196. For a similar confusion between the physiological method and the critical method of Kant, see Adamson : *Philosophy of Kant*, pp. 23, 77, 78.

[1] Green: *Works*, Vol. I, p. 163. It is true that Hume's restricted use of the term 'idea' was, as pointed out by Dr. J. Ward (*Psychological Principles*, p. 46), a retrograde step ; yet, in excluding any reference to body from the original impressions, he was unquestionably truer to the 'new way of ideas' than its author.

We cannot enter at present upon the current controversies regarding the nature and status of the sensa. The question whether they are mind-dependent or not is a difficult one, and this is amply evident from the historical movements of the different theories, concerning the nature of the qualities. Reflections on the nature of motion at the dawn of the modern period led to the distinction between the world as it appears to us and as it is in itself. As a consequence, Galileo declared the mind-dependent nature of a number of qualities which are ordinarily referred to the physical world. This theory passing through Descartes and Locke, falls into the hands of Berkeley as a weapon against the independence of the primary qualities. The latter points out that the same considerations which disclose the mind-dependent nature of the secondary qualities may be equally applied to the primary ones which have been therefore falsely declared as independent. Contemporary realism in making the alternative trial, finds that the considerations which disclosed the independent nature of the primary qualities could in fact be extended to the secondary qualities as well. Previous philosophers, in their opinion, did not see that it was impossible to confer independence upon the primary qualities without at the same time emancipating their ordinary associates. But, some of the modern realists (*e.g.*, Mr. Alexander in considering the tertiary qualities as mind-dependent) have not been able to join this philosophical struggle for independence as whole-heartedly as their more enthusiastic comrades and thus have furnished an occasion to the enemy. For, a future Berkeley may take this as a clue and force the primary and the secondary qualities once more into the state of tutelage or servitude. Others however are more prudent and so cry out that all the things of earth and heaven, all qualities and all relations, are perfectly independent and have no need for a guardian.

Fortunately, however, this question of dependence or independence is not so material at the start as is often thought by the disputants. The representative theory of perception

which forced itself upon Descartes who sought to go from mind to matter must also be the only refuge for those who seek to go from the transient and contradictory to the permanent and self-consistent. "Many of our impressisons," says Hume, "have no external model or archetype," for, the impressions are transient and conflicting existences, while, the external objects are permanent and self-identical. Similarly, Berkeley asks in the Dialogue :[1] "How then is it possible that things perpetually fleeting and variable as our ideas should be copies or images of anything fixed and constant?" Berkeley, therefore, substitutes what is now known as epistemological monism for "a two-fold existence of the objects of sense."[2] But he never dreamt that it could ever be possible for realism to give a coherent account of "nature as it is disclosed to us in sense-awareness, without dragging in its relations to mind."[3]

Hume's difficulties then, we claim, arose ultimately not from the "original assumption of the ideal system," but from the interrupted and variable nature of those perceptions which are revealed to immediate experience. He brings the impressions of figure, bulk and motion as well as those of colour, taste and smell, together with pain and pleasure, and declares that though "both philosophers and the vulgar esteem the third to be merely perceptions, and consequently interrupted and dependent beings," yet closer inspection reveals the same characteristics in the first and the second varieties of perception. It is true that "all of us at one time or other" become unthinking and unphilosophical and suppose that our perceptions are the only objects "and never think of a double existence, internal and external, representing and represented." But when we philosophise, it is not enough to refer to the common sense of mankind or to an implanted instinct for the

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[1] Fraser : Selections, p. 160.

[2] *Cf.* Prof. A.N. Whitehead : *The Concept of Nature*, Ch. II.

[3] *Ibid.*, p. 27. Contrast Bosanquet's position that "the world cannot be a coherent whole without mind"—*Logic II*, p. 321.

justification of the belief in the continued existence of the external objects. As our perceptions are transient, interrupted and conflicting, it is necessary to enquire into the origin of the belief in a continued uninterrupted external world which is independent of the fact that somebody experiences it.

The substitution of the terms sensa or sense-data, perspective or appearance for impressions, perceptions or ideas does not materially help us to solve the difficulties of Hume; and this is amply evident from the conflicting theories propounded to explain the nature and position of sense-datum. The perplexities in the modern account of the distinction between sensations, sense-data and physical objects, and the difficulties thence arising in the selective theory, creative theory and the mixed theory respectively can never be satisfactorily solved, until it is recognised that all contradictions ultimately spring from the false ascription of absolute existence to that which in reality has a complex of conditions all of which are equally important determining factors in its existence. It is immaterial whether we should *call* the sensa mental or physical, created or selected. What really matters is whether we should consider them to be conditioned or unconditioned existences, and this, as suggested above, is at the root of the controversy between realism and idealism. On closer inspection, it will appear that Hume's difficulties ultimately arose from his atomism. The impressions he regarded as so many isolated atoms making their appearance on the animal sentiency and then disappearing, without being in the least affected by the entrance or disappearance. Taking it for granted that the impression of colour, for instance, has an intrinsic nature of its own unaffected by its relation either to other impressions or to the mind, his only means of escape from the interrupted and variable impressions was to reduce our belief in the continued existence of the external world into a fiction of imagination. The perplexities which inevitably arise from separating nature from mind are perhaps

nowhere more apparent than in connection with the categories to which we make a short reference in the remaining part of this essay.

The Realistic Conception of Categories.—The contrast of empiricism with criticism, and consequently the distinction between realism and idealism, appears in its vital form in connection with the ultimate principles of knowledge and existence. The merit of the "ideal system," as indicated above, consisted in reaching, in its analysis of external perception, the standpoint of immediate experience. But Locke, in his zeal against all forms of *a priori* philosophy and the theory of innate ideas, was prevented from reaping the full fruits of the position so assiduously reached by his predecessors. Instead of recognising the part played by the "understanding" in transforming the chaotic manifold of sense-presentations into a world of permanent objects, he sought to derive the ultimate principles of knowledge from the sense-manifold and finally reduced them to mere creatures of the mind. In reviving the doctrine of *entia rationis* of the Schoolmen, Locke was merely giving expression to the spirit of the time. His *tabula rasa* is only the mystic's "globe of light" passed into the hands of a philosopher. The purely receptive understanding of the mystic is freed from the encumbrance of divine influence, and the theologian sinks into a philosopher. But it was not open to the philosopher determined to emancipate thought from the extravagances of *a priori* speculations to indulge in the idea of an eternal understanding, and hence his only alternative was to show the empirical origin of all the eternal verities and the so-called innate ideas. As was to be expected, it is David Hume who perceives the legitimate consequence of this empirical method, and so he raises the problem which he claims to be both important and new, "little cultivated either by the ancients or moderns."[1] What is the nature of that evidence, Hume

[1] *Enquiry*, Green's edition, p. 23.

asks, which assures us of any real existence and matter of fact, beyond the present testimony of our senses? All transcendence of immediate experience, the answer comes, is due to a subjective tendency arising from repetition of similar instances. By means of the relation of cause and effect, Hume thinks, we go beyond the evidence of our memory and senses. But the knowledge of causal relation is not attained by *a priori* reasonings. It is ultimately due to the customary transition of the mind from one presentation to its usual attendant. This conclusion, Hume admits to be extraordinary yet inevitable.

We must avoid at this place the difficult task of estimating the merits of Kant's answer to the difficulties raised by Hume. The widely divergent interpretations of the transcendental deduction of the categories, and the equally divergent views on the merits of the deduction still prevailing among his critics and commentators leave no room for a summary account which will be free from dogmatism. We have undertaken here the humbler task of enquiring whether some of the tenets of contemporary philosophy are not due to the thinkers not appreciating the exact nature of the movement from Hume to Kant. The contrast of the selective with the creative function of the mind, the adoption of the psychological standpoint against the epistemological, the rigid separation between knowledge and reality—these and similar other features which characterise contemporary thought appear to depend on a false view of the first principles of knowledge. Till this error is got rid of, Hume's difficulties will remain unsolved. Indeed the very fact that the thinkers of the present-day sometimes pretend to miss Hume's difficulties is a proof that their systems are founded on a false basis. A consistent empiricist must be able to swear by the legacy bequeathed by the Scottish sceptic, and is expected to have the courage to found the first principles of thought and reality on the observation of the psychical habits of man. They are to be exhibited as certain habits or tendencies

of our minds acquired by a process of sensitive experience in the individual or the race. This conclusion, however, is never drawn explicitly, though it is strongly suggested by some of the characteristic tenets of current realism.

As a protest against the idealist's attempt to consider the entire universe as contents of the mind in some sense or other, the modern realist is bent upon eviscerating mind of all its contents and, if possible, wiping the mind itself out of existence. So he looks about to examine the different things with the label "mental" and his judgment in each case is the same, *viz.*, "away with the impostor." He takes up one by one the abstract and the unreal, dreams and illusions, relations and universals, laws of thought and facts of feeling, and finally the mind itself. On examination it is found that all these items have been erroneously labelled "mental." They must take their seats out there among the objects; and lastly the mind itself must follow suit. Thus current realism aspires to be called objectivism, and its theory of mind, behaviourism. The realist's account of the categories is inspired by the same ideal. The categories are described as pervasive features as distinct from the variable ones,[1] and if Kant referred them to the mind that was because in the age in which Kant and Reid lived, this was the only way of indicating that the world of experience contains pervasive features as well as variable ones. Is this a right interpretation of the doctrine of categories as held by Kant?

To identify the categories with the pervasive features of the world of experience is to put the transcendental enquiry in an extremely misleading light, for it prevents us from seeing the real problem to which Kant's entire labour in the Critique of Pure Reason was devoted. The fundamental problem to which it was the merit of Descartes to draw the attention of thinkers for the first time, and in solving which philosophers were led

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[1] *Space, Time and Deity*, Vol. I, p. 192.

to propound widely divergent theories, is much darkened by this identification. The theories of Occasionalism, Pre-established Harmony and Parallelism are the different attempts to solve this basic problem of modern philosophy, while the pantheism of Malebranche and Spinoza, the monadology of Leibniz, the phenomenalism of Kant, and even the theories of Identity and Panlogism of the post-Kantian period arose out of reflections upon the same problem. This, as is well known, is the problem of the real and the ideal, which Descartes brought to consciousness for which he has been claimed to be the father of modern philosophy. Except in relation to this problem, the Kantian doctrine of categories must remain as the strangest offspring of philosophical perversity. To the subjective idealist he points out that the categories are not mere "creatures of the mind" or "fictions of imagination"; on the contrary, they enter, in the words of Prof. Alexander, as constituent factors into every existent. In opposition to the realist's position, on the other hand, he points out that they are not in Nature abstracted from Spirit, and that if they had belonged to abstract Nature our knowledge of Nature would never go beyond the habits of expectation to which Hume reduced all our inferences from experience. That is, the mentalist and the realist both begin with separating the logical from the metaphysical necessity, and end with reducing the former into mere psychological necessity. The new theory, on the other hand, germinated in the Aristotelian conception of the categories as both "kinds of predicate" and "kinds of being." It is not then a superficial observation that Kant's philosophy is a half-way house to the Hegelian idealism. It is, however, incontestable that Kant was far from identifying his synthetic unity of apperception with the Absolute of the later philosophers. In fact, he protests against this identification in the most emphatic terms; and is equally emphatic against the extraction of a real object from pure logic. But it is no less incontestable that one of the most vital points which he sought to make clear for all time was that the logical

and the metaphysical aspects of the categories are inseparable. Nature which is "self-contained for thought"[1] may be a useful postulate for natural science; but in the philosophy of nature, we cannot accept without examination that postulate which is justifiable only from the abstract standpoint of the natural sciences. The pervasive features of the world of experience and the laws of Nature, when we consider it as externally related to mind can be nothing superior to the mental habits of a species of individuals who are doomed to know Nature through the transient presentations of the senses. These considerations confirm the observations we made on another occasion, and they are so relevant to the present topic that we need not apologize for quoting them here. The idealistic position "is all the more inevitable for a theory of immediate perception of the world, for, representative perception is a necessary accompaniment of realism, however clearly the fact may be disguised under the cover of an ambiguous expression......The embarrassments which the new realists feel in determining the status of the sensum are the inevitable consequence of the abstraction of mind from the objects.........This does not amount to the denial of a possible abstraction of Nature from mind temporarily ...and thinking homogeneously about Nature. But then it is to be constantly borne in mind, that this is after all a useful make-shift, and so in dealing with a nature 'closed to mind,' we have to use words and phrases that cry out for the concrete whole."[2]

Kant, therefore, in his theory of categories seeks to steer clear of the Scylla of absolute idealism and the Charybdis of atomistic sensationalism. The ultimate presuppositions of knowledge are also the ultimate conditions of the world of experience, for, Nature exists only for a rational individual who is constantly guided in his investigations by the *ideal* of a unitary system. Nature reveals herself to man because he is

[1] *Cf.* Whitehead: *The Concept of Nature*, p. 3.

[2] An article in the *Educational Review*, December, 1921.

more than beasts and less than God. An intuitive understanding, as Kant says, is the prerogative of God alone, while animals are condemned to merely sensitive experience. Man, on the other hand, has both sense and understanding, and so Nature exists for him only in so far as the chaotic manifold of sense-presentations which are alone *given* in the strict sense suffers gradual transformation under the intellectual ideal of a thorough-going unity.

We are not at this place concerned with examining how far Kant's account of categories as suggested above can be ultimately maintained without developing it further and carrying it on to the dangerous precincts of absolute idealism. We are only trying to remove some of the misapprehensions and misgivings which appear to cluster round his theory of knowledge owing perhaps to its historical connexion with a widely accepted interpretation of Hegel's philosophy. A student of Kant has no hesitation to offer the warmest reception to the realist in so far as he teaches that the world of reality is not the mere contents of the universal mind, nor is it the unrolling of mental events by a creative imagination or æsthetic activity as taught by neo-idealism.[1] He may accept the realist as a fellow combatant against the attempts to leave the sure ground of experience. His only complaint is that the realist does not sufficiently and always realize that Nature the deciphering of which is the object of natural sciences is not given as a complete fact like colour or sound to the purely receptive sensibility or, to borrow a modern phrase, anœtic consciousness. Nature of course is given in another sense, *i.e.*, in the sense of being independent of the chance movements of individual fancy arising from, say, the laws of association. The laws according to which we consciously or unconsciously interpret Nature are not due to arbitrary

[1] It may be permissible to observe here that if he is ever asked to choose between the orthodox Hegelian position and the creative idealism of Croce and Gentile, he will surely prefer the former as more in keeping with the transcendental teachings of Kant.

impositions of mental forms on a foreign material. Understanding has its inherent laws which it can no more violate than water can refuse to flow downwards. These ultimate laws are obeyed by all scientists though they may not be conscious of the fact that they are obeyed, *e.g.*, every scientist must admit that nature is a system. All his attempts to revise and remodel knowledge are actuated by the belief that Nature is a complex whole. Every new theory which is but an admission that we failed so far to understand Nature is born of the incapacity of the old theory to present Nature as a systematic whole. So far the idealist and the realist must go together. But here the question inevitably arises: how do we know that Nature is a whole? This knowledge surely cannot come from sense which only presents us with fleeting and conflicting sense-data. We might be tempted here to say that Nature is there completely independent of the scientist's mind, but it is revealed to him only because he is a sensitive as well as a rational being. Kant however goes a step further, and insists that Nature about which the scientist forms his theory is not *given in any other way* than through the theory, and so it is impossible to compare the theory with something external to it in order to see how far his knowledge corresponds to natural facts. The criterion by which he can judge whether he has correctly known Nature or not is to be found in the laws of understanding itself. So, in this connexion what is revelation from one side is realization or construction from another.

To pursue further the suggestions made above will be to expound the Kantian theory of knowledge as a whole which is far from our present object. It is widely admitted by the exponents of the critical philosophy that the dream of making Kant consistent will never be realized. Every student of Kant is compelled to follow what he thinks to be the main drift of the master's teaching. The above suggestions are meant to indicate the particular line of

interpretation which the critical philosophy admits of, and which may be necessary at a time when distinguished thinkers are offering a completely realistic interpretation of Kant's categories. The perplexing and apparently contradictory statements in which Kant has couched his thoughts may be open to diverse interpretations equally plausible and sound. But to read realistic meaning into his doctrine of the categories is to transfigure his position beyond all recognition. The students of Kant have so long been taught to guard themselves against that false view of the categories which was made current by such logicians as J. S. Mill. The 'summa genera' of the scholastic logicians are *not* the Kantian categories. The confusion was due to the Schoolmen not realizing the profound significance of the Aristotelian theory which had necessarily passed through their hands. But it is now equally necessary to avoid the other misconception which probably has its source in the criticism which the Hegelian Dialectic has received from the critics like Trendelenburg, Von Hartmann and Haym.[1] The chief complaint of Trendelenburg against the claim of the Dialectic Method is that every step of the advance is empirically conditioned. Each of the categories is only an abstraction from the fulness of actuality, and so craves to escape from this forced position; and the dialectic method is simply the act by which we retrace our original abstraction.[2] We are not in a position to judge how far Hegel really

[1] In fact, there are striking resemblances between some of the tenents of current philosophy, and what Trendelenburg taught in his *Logical Investigations.* Motion, Space and Time, for example, are declared by him as undefinable. Space and Time are further thought to be products of Motion or sides of it obtained by abstraction. *Cf.* Whitehead, *Ibid.*, p. 33, and the following pages, where he too calls Space and Time abstractions from the passage of events. There are naturally striking differences between their views arising chiefly from the current conception of the creative advance of a four-dimensional world; but the resemblances are no less striking.

[2] For a criticism of this view, see McTaggart: *Studies in Hegelian Dialectic*, Ch. II.

meant what his critics attribute to him. It is at least strange that he should have taught a doctrine which is ultimately based on a confusion between thought and existence, knowledge and being. But one thing is certain, namely, that he, coming as he did after Kant, could not have meant his categories to be mere abstractions. In fact, the reduction by Hume of the general or universal elements of experience into the contingent psychological result of the particular "perceptions" was due to the abstract method initiated by Locke; and the wrong conception of the categories was ultimately born of this abstraction. There is, as Green points out,[1] a wrong view of the categories and a right one. "The right one regards them as the relations or formal conceptions, without which there would be no knowledge and no objective world to be known. They are not the end but the beginning of knowledge, not ultimate truths, but truths which we already know in knowing anything, though the correct disentanglement of them is in one sense the great problem of philosophy...The wrong view goes along with the false notion that the essential of thought is abstraction. ...According to one they are really apart from the objects of ordinary knowledge and experience, and are known by abstraction from these; according to the other, all objects of ordinary knowledge and experience are determinations of them, so that we know them in knowing the former, though we do not know that we know them." This brings out clearly the deficiencies of the empirical attitude towards experience, an attitude which is characteristic of all minds so long as they do not care to step beyond the "face-value" of the things of experience. It is the distinctive feature of empiricism to take experience as an ultimate fact without enquiring into those conditions which make experience possible, and the consequence is that these transcendental factors of

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[1] *Cf. Works*, Vol. II, p. 207.

experience are supposed to be either mere "creatures of mind" or mere "features of the world." In fact, Locke's view of categories as mere creatures of mind to which nothing corresponds in nature, and Prof. Alexander's interpretation of them as mere pervasive features of the world to which nothing corresponds in mind, are based on a common assumption—an assumption which was expressly rejected by Kant.

The point which calls for special emphasis in this connection is that the empiricists before Kant conceived the relation between the knowing mind and the known object as purely mechanical and accidental. Locke, for instance, takes mind as something existing independently of the material world which come into relation with each other in perception. The material world causes certain ideas in the mind which the mind analyses, combines and recombines in various ways, thus producing the complex ideas corresponding to which there are no objective archetypes. This abstraction of the subject from the object became current in philosophy since the Cartesian doctrine of *cogito ergo sum*, and Locke had simply to purge it of its rationalistic implications in order to fit it into his system. So, he retained the mind-substance of Descartes, but rejected the latter's assumption of innate ideas. The *tabula rasa*, in the first instance, passively receives the simple ideas and then works upon these materials in diverse ways. Kant's originality here consists in exposing the groundlessness of this assumption, and in pointing out the perfect correlativity of the subject and the object. A subject which waits for the material world to produce ideas in it is a logical abstraction as much as an object apart from the subject. The various powers which Locke attributes to the mind can belong to it only in so far as it is a self-conscious individual; but self-consciousness implies consciousness of an objective world and hence experience must be already a fact before the mind can operate upon it and then derive the complex ideas. The necessary relations which

empiricism explained as born of repeated observations through the laws of association are imbedded in that very experience, apart from which there can be no mind to make those observations and no object to be observed. So, the laws of association, far from accounting for the origin of experience, presuppose a conscious subject and a world of objects, that is, the associative faculty can operate only when there is a mind which consciously apprehends the data to be associated, and this conscious apprehension is possible only in so far as those data conform to the transcendental conditions of experience. If then the categories are these conditions, they make association possible, and cannot therefore be themselves due to association. "Were cinnabar, for instance, sometimes red and sometimes black, sometimes light and sometimes heavy;......there could be no empirical synthesis of reproduction," because the representations would not be subject to any rule and so could not fit into a unitary experience. This is Kant's central polemic against the empirical method of approaching experience. Empiricism explains those factors as later derivations which being at the basis of all knowledge and experience make this derivation itself possible.

It will appear from these considerations that the fundamental distinction between the empirical and the transcendental treatment of the categories consists in this that empiricism takes experience as a given fact without further explanation of that fact, and hence the categories for him are but empirical generalizations which are abstracted from experience; transcendentalism, on the contrary, discovers in the categories the very conditions of experience, and not mere empirical concepts or contingent products of experience. As a matter of fact, the empirical concepts depend upon the categories in so far as experience from which the former are derived is made possible by the categories. The categories may also be called the indispensable condition of a unitary experience

which makes possible the unity of apperception. As Mr. N. K. Smith puts it, the categories may be regarded as expressing the minimum of unity necessary to the possibility of self-consciousness. "If sensations cannot be interpreted as the diverse attributes of unitary substances, if events cannot be viewed as arising out of one another, if the entire world in space cannot be conceived as a system of existences reciprocally interdependent, all unity must vanish from experience, and apperception would be utterly impossible."[1] The ultimate necessity of the categories, therefore, is due to its connection with self-consciousness. They are the modes of unity under which the sense-manifold must stand in order that subject-object experience may be possible. Empiricism, then, entirely misunderstands the nature of the categories when it looks upon them as the most abstract generalizations from experience. This misunderstanding leads to an important consequence. Once we look upon the categories as abstract concepts, they cannot be held to have any necessary connection with experience, and so they become mere "creatures of mind" or "fictions of imagination." Now, if we probe a little deeper into this empirical view of the categories, we tumble upon one of the fundamental assumptions of neo-realism, namely, that the relations into which the different parts of experience enter are purely arbitrary and adventitious, that the particular parts exist in their own right which are afterwards forced into different complexes. The mind apprehends the different sensa in their distinctness and then combines them into various things, so that the latter are but clusters of sensa which go together we do not know why. Similarly, the mind receives two sensations in succession which being repeated several times generates a tendency of the imagination to pass from the one to the other, and here also there is no necessity why one should follow the other. The same line of thought when applied to the unity of consciousness must result in

[1] *Commentary*, p. 253.

the assertion that this unity also is purely a fiction generated by the different elements which are real apart from this unity. This is the *reductio ad absurdum* of the original dogma of empiricism—the dogma, namely, that the elements are real apart from the whole, into which they may happen to enter. It is hardly necessary to state in detail the points of agreement between Hume and contemporary realists in this respect. It is enough to remember that the conception of mind as a mere continuum of acts without an agent to whom those acts belong has been forced by the "empirical" method even upon such a realist as Prof. Alexander who has found it necessary to part company with those realists who "look at their mind from the outside and do not, as it were, put themselves into the place of their own minds."[1]

Ideal Construction.—It may be pointed out in conclusion that, even if we suppose the physical world to be independent of mind, there are difficulties in considering the pervasive features of that world as either objective or subjective exclusively; and these difficulties increase in proportion to the pervasiveness of those features. This may be illustrated, *e.g.*, from the Law of Contradiction. Is it a law of thought or of thing? In rejecting what he thinks to be the Kantian account of the *a priori* elements of experience, Mr. Bertrand Russell[2] observes that there are strong reasons for thinking that the view which led to the "laws of thought" being so named is erroneous. For, "what we believe when we believe the law of contradiction, is not that the mind is so made that it must believe the law of contradiction. *This* belief is a subsequent result of psychological reflection, which presupposes the belief in the law of contradiction." Mr. Russell, however, does not say explicitly that it is a law of things in abstraction from thought. On the contrary, he insists that "the belief in the law of contradiction is a belief

[1] *Space, Time, and Deity*, Vol. II, p. 109.

[2] *The Problems of Philosophy*, p. 136.

about things, *not only about thoughts*."[1] In so far as this is the case, he really subscribes to the Kantian view. Kant could never be persuaded to imagine that the *a priori* forms of experience are mere subjective beliefs. On the contrary, he waged a continued warfare against this doctrine. When, therefore, it is said that the *a priori* forms belong to the constitution of the mind, what is meant is, *not* that they are purely subjective, but that they are the ways in which we are compelled to think in thinking of any object of experience. And it must be acknowledged that the only criterion, in the last resort, by which we can distinguish between the fanciful and the objective is whether we are obliged to think in a particular way. To such critics of Kant as think that "ideal construction is a contradiction in terms, unless it refers solely to mental imagining,"[2] we must respectfully reply, in the words of Green, that "it is not understood that his doctrine of *a priori* forms of experience refers not to subjective beliefs but to those relations of phenomena which are necessary to the existence of a knowable objective world."[3]

The failure to appreciate the place of ideal constructions in our knowledge, and the consequent separation of the ultimate laws of nature from the fundamental laws of thought are then intimately connected with the realistic interpretation of the doctrine of categories. This interpretation, we must insist at the risk of repetition, does not bring out the correlativity of the real and the ideal which it was one of the chief aims of Kant's doctrine of categories to establish. Yet, this aspect of the doctrine it is important to recognise not only on its own merits, but also to understand Kant's historical position. The problem of the Ideal and Real has been called "the axis on

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[1] Italics not in the original.

[2] *E.g.*, H. A. Prichard : *Kant's Theory of Knowledge*, p. 244.

[3] *Works*, Vol. III, p. 129. *Cf.* Lotze : *Logic*, II, p. 314 ; Bosanquet : *Contemporary Philosophy*, p. 176.

which the whole of modern philosophy turns."[1] It is one of the chief results of Kant's transcendental investigations that the ordinary conception of the relation between knowledge and reality is untenable. The categories are not merely the universal features of facts of experience, but also the universal modes or forms of thought involved in experience. The result of this view is, as put by Mr. Green, "to overcome the separation, which in our ordinary thinking we assume, between the faculty or capacity or subjective process of experience on the one side and the facts experienced on the other."[2] Much of the mystery that enshrouds ideal construction disappears when it is observed that by calling understanding the source of the categories which from the side of the objects are their pervasive features, Kant was trying to make clear a truth which was indicated by Aristotle when the latter called the categories both "modes of being" and "modes of predicate." Whatever is real or can be thought of as real, must come under one of the categories, and that which is neither a substance, nor a quality, nor any of the other categories, is indistinguishable from nothing; it is matter without form, and hence unknowable and incapable of standing, to borrow a current expression, as the subject of significant propositions. Similarly, the result of Kant's investigation was to bring out the essential identity of the forms of understanding and the forms of object. In other words, he exploded the false basis, upon which the separation between the subjective and the objective elements of knowledge was made by his predecessors, and this he did by showing that the laws according to which thought works in knowledge are inseparable from the universal laws according to which objects or Nature as a system of things can exist for us. The necessity of thought and objective

[1] Schopenhauer's Essay: *The Doctrine of the Ideal and Real*, p. 15.

[2] *Prolegomena*, Sec. 34.

necessity are inseparable, so that to understand the fundamental laws of objects is also to gain an insight into the basic laws according to which thought works. Prof. Alexander's account, then, we are inclined to believe, ignores this aspect of Kant's doctrine, and it is this which is responsible for the widespread misunderstanding which he shares with Kant's critics like Mr. H. A. Prichard who think that Kant was unconscious of a fundamental objection to his account of knowledge, though the objection is "so obvious as to be hardly worth stating; it is of course that knowing and making are not the same."[1] It is hardly necessary to add that this, far from being an obvious objection, is one of the most permanent intellectual conquests that were ever achieved by a thinker.

[1] *Kant's Theory of Knowledge*. p. 236.

ON GREEN'S "SPIRITUAL PRINCIPLE."

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Green's philosophy is above all a philosophy of relations. The world for him is not a bundle of unrelated bits, or bits which cannot be related, but a whole of interrelated parts. Relations are of the essence of things (Sec. 20). What he wishes to emphasise is that the world is and makes for a unity. It is an error to suppose that relations on his system do away with substance. Green allows both for material and spiritual substance.[1]

It is in the ordinary act of perception that he finds the real starting point for his philosophy—the bringing together of the timeless and that in time (Sec. 65).[2] While we consist of relations, *we* are more than relations. The relations do not *determine* us, but we determine them, both in perception and in motive.[3] We are not to conclude hurriedly, however, from this that our selves are substances without attributes—our selves or the divine self.[4] Green has

[1] "It is not denied that there are material substances, but their qualification both as substances and as material will be found to depend on relations." (Sec. 53.) Again, we are not reducible to the series of our actions, nor that series to ourselves (Sec. 36). See also Sec. 80.

[2] "There is more hope of result if the controversy [as to the transcendence of man] is begun lower down, with the analysis of an act which it is not doubted that we perform."

[3] "It [motive] results, as perception results, from the determination of an animal nature by a self-conscious subject other than it." (Sec. 91.)

[4] "Just as we hold that our desires, feelings, and thoughts would not be what they are—would not be those of a man—if not related to a subject which distinguishes itself from each and all of them ; so we hold that this subject would not be what it is, if it were not related to the particular feelings, desires, and thoughts, which it thus distinguishes from and presents to itself." (Sec. 100.)

no place for the abstract universal. The followers of this abstraction are spoken of thus: "They fancy the divine to be in the grave of a universal, from which all the life of particularity is withdrawn." They are spoken of as suffering from "a metaphysical misapprehension" which "would efface all definite predicates from the language of religion, and reduce it to a prolonged monotonous sigh"; and they are characterised as people "who lift their eyes upward, but they know not whither, who are thrilled with an awe but are forbidden by their philosophy to say of whom."[1]

In Green we have both sets of passages—the spiritual principle (the self of man or God) determining and being determined by its relations to the world. We have to note both these aspects to arrive at a true interpretation. The paradox involved in the notion does not trouble him. On fundamental questions like these there can be no arguing.[2]

The timeless in time, the unlimited putting on limitations, this is the besetting fact of everyday life for Green. He divides for the purposes of his exposition, life into Knowledge, Faith, and Morals. Throughout these provinces, the eternal consciousness or reason has been operative and the constitutive factor.[3]

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[1] The quotations are all from Green's Works, Vol. III, p. 79.

[2] "......why the whole should be what it is, why the mind which the world implies should exhibit itself in a world at all, why it should make certain processes of that world organic to a reproduction of itself under limitations which the use of such organs involves —these are questions which, owing perhaps to those very limitations, we are equally unable to avoid asking and to answer. We have to content ourselves with saying that, strange as it may seem, it is so ....The wonder in which philosophy is said to begin will not cease when this conclusion is arrived at; but till it can be shown to have left some essential part of the reality of the case out of sight, and another conclusion can be substituted for it which remedies the defect, this is no reason for rejecting it." (Sec. 82.)

[3] "Speculation and moral action are co-ordinate employments of the same self-conscious soul, and of the same powers of that soul only differently directed." (Sec. 149.) "Under different relations, or in different modes of itself, reason is the source alike of faith and knowledge."—Works, Vol. III, p. 266. "The divine mind touches, modifies, becomes the mind of man, through a process of which mere

Reason is the common source of this threefold life; "not, however, abstract reason, but reason as taking a body from, and giving life to, the whole system of experience which makes the history of man."[1] For its creation, preservation and growth, it needs the fullness of this life already realised in a self, *i.e.*, God.[2]

If we are to understand this relation between God and man in Green's philosophy, we have first to enquire as to the exact meaning of the terms "reproduction" and "identity" as used by him. "Reproduction" is thus explained. The human consciousness is a reproduction of the divine mind "in respect, at least, of its attributes of self-origination and unification of the manifold." (Sec. 77.) This reproduction is further explicated as the possession of the attribute, by the human mind, of the power of self-objectifying (Sec. 101). As to "identity" we glean as follows. That "identity" does not do away with duality of consciousness is represented by Sec. 86: There could be no nature for us but for an action of a spiritual self-distinguishing subject "in or as our soul." Identification is expressly distinguished from determination (and understood as communication), thus conserving human individuality in Sec. 77. Facts and events are determined by the spiritual principle in a sense other than that "in which we ourselves are not so much determined by it as identified by it with itself, or made the subjects of its self-communication." "Identity" is declared and found between the simplest beginnings of knowledge and the eternal consciousness reproducing itself in it, in the possession of these common characteristics: "the presentation of a many in one, the apprehension of facts as related in a single system, the conception of an order of things."

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intellectual conception is only the beginning, but of which the gradual complement is an unexhausted series of spiritual discipline through all the agencies of social life."—Works, Vol. III, pp. 239-40.

[1] Works, Vol. III, p. 239.

[2] Green has worked out this epistemological proof of his for the existence of God in *Prolegomena*, Section 187.

(Sec. 72.) God is spoken of as the Being "with whom we are in principle one; with whom the human spirit is identical, in the sense that He is all which the human spirit is capable of becoming." (Sec. 187.) To stray beyond the *Prolegomena* we find Green sufficiently alive to the dangers of a misconceived identity between man and God. "To the individual man, no doubt," he says, "the absoluteness of his limitations never wholly vanishes. The dream that it can do so is the frenzy of philosophy, and its practical effect may be seen in the immoral heresies of early Christendom, which were mostly crude attempts to realise in action ideas which for us have only a regulative and anticipatory truth.[1] Again, "Language which seems to imply its [*viz.*, of the human self] identification with God, or with the world in its spiritual reality, can lead to nothing but confusion."[2] A full summing up of what Green means by "identity" is perhaps to be found in the following passage: "Our formula then is that God is identical with the self of every man in the sense of being the realisation of its determinate possibilities, the completion of that which, as merely in it, is incomplete and therefore unreal; that in being conscious of himself man is conscious of God, and thus knows that God is, but knows what he is only so far as he knows what he himself really is."[3]

Before we can be sure of making the human personality, the ethical human self, safe in Green's system, we have to ask ourselves first, what is Green's view of sin. Green expressly makes man the author of sin, justifies "remorse," "and in such a case," he adds, "the evidence of consciousness, fairly interpreted, is final."[4] The lack of harmony between "will" and "intellect" in us is also allowed..[5] In Section 189 he speaks of "the idea of an absolute value in a spirit which we ourselves

[1] Works, Vol. III, p. 86.
[2] Works, Vol. III, p. 145.
[3] Works, Vol. III, p. 227.
[4] Sec. 108.
[5] Sec. 137; Sec. 177.

are." Answering the criticism whether a doctrine of identity does not make God responsible for the sin of man, Green seeks to conserve the reality of sin without making God the author of it. The argument is too close-packed for compression and the passage is best appreciated in its completeness: "sin is the effort to actualise one's possibilities in that in which they cannot be actualised, *viz.*, in pleasure. It is gradually being overcome, while perhaps it seems to be gaining strength, in the moral discipline which directs the same effort after self-realisation into a truer way of attaining its end; and this discipline lies in the perpetual sense of failure and disappointment, in the remorse and despair, in the self-contempt and self-reproach, of which only a self-seeking subject is susceptible. Thus through 'mortal yearnings' we ascend towards a higher object; through influences born of self-consciousness the presentation of a self satisfied by that which cannot satisfy is superseded as the moral motive by that of a self actualised in a life like itself eternal. Sin, then, in itself, though not for the consciousness of the sinner, is no final reality, but only the possibility of this adequate actualisation of self in which it is overcome; and in saying that God is this adequate actualisation, the final reality to which all our possibilities are relative, we have said that in him sin as sin is not, but only sin as overcome. At the same time (and this truth is complementary of the other), but for his communication of himself to us in possibility, as our self, we could not be sinners." [1] A second question to be asked under this head is what are we to think of Green's statement of the human soul as timeless and of his equating God and the world. The most striking statement as to the former is to be found in the following passage: "Should the question be asked, If this self-consciousness is not derived from nature, what then is its origin? the answer is that it

[1] Works, Vol. III, p. 226.

has no origin. It never began, because it never was not. It is the condition of there being such a thing as beginning or end. Whatever begins or ends does so for it or in relation to it."[1] In seeking its interpretation, we should remember that Green accepts the evolutionist's point of view that man appears late in the history of this planet.[2] The passage therefore cannot be taken quite literally. "It never began, because it never was not" does not necessarily postulate the eternity of the soul, but characterises the timelessness of self-determination. In this sense we find Green speaking of an act of self-determination as a "timeless act" (Sec. 101). He speaks of "a self-presenting and in that sense, eternal subject" (Sec. 101). Again "The act of adoption [of a desired object] is the act of a subject which has not come to be; the act itself is not in time, in the sense of being an event determined by previous events." (Sec. 101.) The co-eternity of man with God, the denial in other words of man's creaturely character, does not enter into discussion at all. But what about the co-eternity of the world, it might be asked? Section 66 tells us "We cannot indeed suppose any real separation between the determinant and the determined. The order of becoming is only an order of becoming through the action of that which is not in becoming; nor can we think of this order as preceded by anything that was not an order of becoming."[3] This does not mean that the world as we know it is eternal,[4] but that the *idea* of it existed eternally

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[1] Sec. 101.

[2] We get the body but not the mind, according to Green, from the brutes. (Sec. 84.)

[3] *Cf.* also Sec. 75.

[4] Mr. Balfour, *e.g.*, considers the Spiritual Principle apart from Nature "a mere metaphysical abstraction," and "in combination with Nature" holding in suspension "without preference and without repulsion, every element alike of the knowable world." "Of these none," he adds, "whatever be its nature, be it good or bad, base or noble, can be considered as alien to the absolute: all are necessary, and all are characteristic."—*The Foundations of Belief*, pp. 145-6.

in the mind of God. That there is, as Green elsewhere points out, "a divine idea of the world," "by which we mean," he goes on to say, "to speak after the manner of men, the purpose of God in the creation of the universe, that conception of his works which is ever present to his mind, not as we see them 'through a glass darkly,' but in that perfection which even to our eyes they are destined one day to attain."[1]

It is not to be overlooked that while Green is against all premature views of identity between Man and God, his doctrine of man's end being the fullest development of all his capacities does eventually lead to man becoming God, or the deification of man (Sec. 189). The life of completed development, as it already exists in God or is going to be realised in man, is spoken of as possible of description only in negatives (Sec. 172). We shall go far wrong if we think a blank agnosticism as the point where Green leads us to here. On the other hand, we shall find, on examination, that Green presents us with a very rich positive content of the completed life. Section 189 pictures it as a state of self-conscious being and one where we have a reconciliation of the claims of persons. Section 288 asserts, "it must be a perfecting of *man*"—the whole man, as we would say. But this emphasis on negatives has a twofold object. First, to bring out that our knowledge has, in the process of development, to undergo considerable transformation. This has to be taken with the qualification of the assertion of continuity between the incomplete stages and the completed state. Secondly, that our present understanding is unequal to the task of comprehending, though not apprehending, the world as the totality of things. As he puts it fully in his own words: "To know God we must be God. The unifying principle of the world is indeed in us; it is our self. But, as in us, it is so condi-

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[1] Works, Vol. III, p. 11.

tioned by a particular animal nature that, while it yields that idea of the world as one which regulates all our knowledge, our actual knowledge remains a piecemeal process. We spell out the relations of things one by one; we pass from condition to condition, from effect to effect; but, as one fragment of truth is grasped, another has escaped us, and we never reach that totality of apprehension through which alone we could know the world as it is and God in it. This is the infirmity of our discursive understanding. If in one sense it reveals God, in another it hides him."[1]

What Green seeks to do in his philosophy is, it seems, to give value to human history without limiting the life of God to the life of this world. He, however, sees no way of doing it, *viz.*, safeguarding human values, without carrying *in some way* the experience of change into the heart of the changeless.[2] For what are the alternatives? Either withdraw God from the world and reduce experience to illusion or submit to the position of a growing God. Green would assure us that his conception need not be so hopelessly strange. For in the act of perception we have the same principle—change being predicated of the changeless. We here have a humble clue, and Green would call us to work it to light our dim way through this difficult region.

It is interesting to note how later philosophers have been disposed towards this problem. In his early lectures on "Theism," we find Prof. Pringle-Pattison, while maintaining the transcendence of the divine life, still asserting that the world

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[1] Works, Vol. III, p. 145.

[2] We take this to be the philosophical significance of the doctrine of Ascension in Christian Theology. *Cf.* : "When therefore we declare our belief in Christ's Ascension, we declare that He has entered upon the completeness of spiritual being without lessening in any degree the completeness of His humanity. The thought is one with which we need to familiarise ourselves. We cannot indeed unite the two sides of it in one conception, but we can hold both firmly without allowing the one truth to infringe upon the other."—Westcott, *Historic Faith*, p. 81.

process means "*truly an enrichment*" of its own life.[1] In his later Gifford lectures, again, we find him on one page[2] asserting that "the temporal view of things cannot be ultimate" and progress "is unintelligible as applied to the whole"; and on the very next,[3] the seemingly contradictory but really complementary statement, "Change or development in time may be a fundamental feature of reality, but it cannot literally *be* reality, life, or consciousness." A bolder line is struck out by Sir Henry Jones who makes the very relevant point that the conception of divine immanence "seriously entertained involves the rejection of the idea of God as perfect in the sense that he is unchangeable."[4] And he roundly asserts that "the idea of God as the perfect in process" is "endlessly more attractive and, I believe, more consistent with our experience in the present world than the idea of a Divine Being who sits aloof from the world-process, eternally contemplating His own perfections."[5]

"A determination of events in time by a principle that is not in time"—the reader of Green gets tired of the endless changes which he rings on this one assertion of his. A competent judge declares that "it may almost be said to constitute his entire system."[6] Green would not be convicted of using vain repetition, if his reiterated emphasis leads philosophical speculation not to recede from the point he has won in this matter. It is, we fear, cannot be done without loss to the gains of philosophical conquest.

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[1] *Theism*, p. 35.

[2] p. 383, *Idea of God*.

[3] p. 384, *Do.*

[4] p. 358. *A Faith that Enquires.*

[5] p. 360, *Do.*

[6] Pringle-Pattison, *Hegelianism and Personality*, p. 4.

Note.—The references to the sections in this paper are to those in Green's *Prolegomena*.

PARASITISM IN INDIA: ITS COST & CURE

BY

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In a preliminary note on *Pauperism* in India, published in Vol. I, No. 3 of the Indian Journal of Economics, Mr. Padam Sen Jain, M.A. some time Reader in Economics (old style), University of Allahabad, has made out a very strong case for the study of this problem in India. The present study is inspired by a perusal of that article, but its scope is a bit enlarged than contemplated by Mr. Jain.

India at the best is a poor country, but it is not the problem of poverty in India that I propose to discuss in the following pages. Not because the problem of poverty in India is not an important one, but because it is so complex and so big that it is not possible to discuss it within the purview of a paper like this. It requires a prolonged study for a number of years and then a pretty large volume to discuss it in all its details. Here I propose to discuss and that too tentatively with a view to arouse interest and call for criticism only those aspects of the problem which deal with people, who may with fairness be classed as parasites, that is, people who live upon the wealth produced by others, and who directly or indirectly contribute next to nothing to our country's annual production. In this class, I am inclined to place the following categories of persons: (i) the *zemindars*, (ii) the *mahants* and *gosains* with their *akharas* that are found in places like Mathura, Allahabad, Benares, Gaya, Puri, Hardwar, and Rameshwaram, and who may be

looked upon as big religious aristocrats, having large resources in land and other property, and (iii) the paupers as defined by Mr. Jain. If we turn to the *Classification by Occupation* (Census Report, 1921, Vol. II), we find under Class A—Production of Raw Materials, and sub-heading I—Pasture and Agriculture (No. 1) Income from rent of Agricultural land, 99,86,419 persons. In Class C—Public Administration and Liberal Arts, sub-heading VIII, No. 166—Religious mendicants, inmates of monasteries, etc., 5,24,978, and in No. 165—Priests, Ministers, etc., 15,10,140. Again in Class D—Miscellaneous, under sub-heading XII—unproductive—No. 189—Beggars, vagrants, witches, wizards, etc.—28,82,641. Adding up all these unproductive classes we find that, year in and year out, India maintains about 149 lakhs of persons, who make absolutely no return for what they consume. An enormous number, indeed, to be supported in idleness by a country in which the average income per head is somewhere about Rs. 9 as. 12 per month, and that too according to the most sanguine estimate so far made![1]

If in the average each of these persons consumes commodities to the value of, say, Rs. 3 per month,[2]—and this expenditure per month is not much—then there is diverted every month a sum of more than Rs. 4½ crores. That is to say, viewing from the strictly economic point of view, and thrusting all sentiment into the background we throw into the sea, as it were, a sum of Rs. 54 crores every year. It may sound preposterous, yet it is true that poor India spends this huge sum every year without getting any economic return for it. And yet this is on the basis of a very

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[1] Findlay Shirras.

[2] This is the standard adopted by Mr. Jain. As a matter of scientific accuracy it should be more than this now, as the prices are higher than what they were in 1916. Taking the index number of prices in 1916 as 100 we find that the price level now (1924) stands at 115. Therefore we should take the figure as Rs. 3 as. 4 instead of Rs. 3.

low estimate. The expenditure per head of Rs. 3 per month, may be true of our beggars, vagrants, witches and wizards numbering 28,82,641. But it could by no means be true of our priests and ministers numbering about 15 lakhs, or of the rent-receiving class numbering about a crore. Persons belonging to these classes must be consuming much more than this sum. Even as it is, it is enough to stagger a sober student of facts and figures, about (i) the total revenue of India, and (ii) the expenditure on such development services as *Education, Sanitation, Agriculture, Industries, and Co-operative Departments.* These are the services which are being starved for want of funds, and their starvation is arresting the future progress towards greater prosperity of our poor country; and yet we are wasting almost 54 crores of rupees every year without any visible or invisible return.

The rough study carried out above has given us a rough and ready idea of the enormous waste. Now let us be a little more scientific. Taking our first category, that is, persons living on income from agricultural land, we find that the total number assigned to this class is 99,86,419. Out of these, 2,880 are partially agriculturists, that is, though they are securing some income from the rent of agricultural land, they are engaged elsewhere and do take part in some sort of useful national activity. This leaves us 99,83,539 persons who live only on the rent of agricultural land. Out of these there must be some who do take some important part in the direction of agricultural industry, and taking these "some" as 10 per cent. of the total, we finally come to 89,85,185 or about 90 lakhs of persons who live on rent, and whose only business in life is to collect rents, to oppress the tenants, to fight law suits amongst each other, and to eat, drink and be merry.

In our second category we have under No. 165 15,10,140 persons. There must be some out of these who are

real priests and who do minister to the spiritual needs of the people, and taking such as forming about 25 per cent. of the total, we find that the final number is near about 11 lakhs of persons. Again in the same category under the sub-head 166—religious mendicants, inmates of monasteries, etc., we have 5,24,978 persons. Perhaps 5 per cent. of these are such who are really striving for spiritual progress. This means that the real total number belonging to this class is near about 5 lakhs. And finally there seems to be no need of making any such allowance for our third category to which about 29 lakhs of persons belong.

Now, if for the sake of greater accuracy it was necessary to make some allowance in the number belonging to each class, then for the same reason it is equally necessary to apply different standards of expenditure per head to the persons belonging to the three separate classes. Rs. 3 as. 4 per head may be quite all right for the beggars and vagrants, but it could by no means give us an idea of the rent-receiving class, or of the priestly class. Their standards of consumption must necessarily be higher, and we should not be much beyond the mark if we were to adopt (i) Rs. 3 as. 4 for (a) beggars and vagrants, etc., (b) religious mendicants and inmates of monasteries, etc., (ii) Rs. 4 per head for the priests and ministers, and (iii) Rs. 5 per head for the rent-receiving class. If these figures err, as they certainly do, then they err on the side of deficiency rather than on the side of excess. This means that (1) on 90 lakhs of rent receivers we are spending $5 \times 12 \times 90$ lakhs of rupees per annum or 54 crores; (2) on priests and ministers Rs. $4 \times 12 \times 11$ lakhs of rupees per annum or 528 lakhs; (3) on religious mendicants and inmates of monasteries $2 \times 12 \times 15$ lakhs of rupees or 240 lakhs of rupees, and (4) on beggars and vagrants $3{\cdot}4 \times 12 \times 29$ lakhs of rupees or about 1,183 lakhs of rupees per annum. Taking the total of all these classes we find that every year we are wasting about 73·5 crores.

A staggering figure indeed !!! And this should set athinking all thinking men in our country. We have been harping for years past on foreign drain, let us harp for a while at least on this inland drain if we wish to think of drains at all.

And these classes are not a drain on our economic resources alone. They are a moral and a social curse as well. To see hundreds of apparently well-fed and healthy persons walking about leisurely with no care in the outside world sows evil seeds in young hearts. The youngman who is struggling how to keep himself above water by honest hard work is sorely tempted by this apparently easy mode of life and not unfrequently lays down the shovel for the mendicants' bowl. Even this is not all. The class of mendicants, inmates of monasteries, beggars, vagrants and witches is the most flourishing centre for the recruitment of the criminal as well as his most secure hiding place. It is not a rare experience in India to hear of cheating, robbery and even murder done by persons who were almost worshipped by the ignorant poor and superstitious people as great religious devotees. It is within the folds of this class that girls from their homes are first taken after being kidnapped and then find their way to the brothels in the cities. And if it is this class that directs the flow of young blood towards the stream of our national shame, then it is the rent-receiving class that builds temples to the God Bachus on the banks of this stream and maintains our depraved womanhood in its glorified shame, and thus provides a strong incentive for many an unsophisticated soul to dive deep for the balls of blood that appear to their dazed eye, as shining pearls at the bottom of this river of sorrow.

Enough of this to convince us that there exists a case for some sort of interference with the people belonging to these classes in the economic and moral interests of the country. The problem how to interfere is not, however, a simple one, and it is a difficult matter to determine the exact lines on which to proceed.

Taking the class of rent-receivers first. It is a class that if it could be made conscientious, and alive to its responsibilities, could do much to hasten the regeneration of despoiled India. The problems of India in all their ugliness in the living present, and in all their bloom in the budding future are in rural India, and the rent-receiving class with its wide resources in material requisites of life, its broader outlook and its higher standard of living than the masses living around it could do a lot to hasten the future day, which is yet indistinct, when the countryside would be but a blooming field of flower and fruit. It is within the power of this class. So far it has failed to do what it should have done. Either it should mend its ways, or we should end it. This is a class which is the creation of the British rule, and if within that period, that is, from to-day till the day when Land Revenue Administration is transferred to popular legislature the class does not give evident proofs of its determination to emulate the English landlord as contemplated by those who created this class, then the breath of the Law that brought it to life should be utilised to take life out of it.

To mend is in its power and to end in ours. The choice is still with the class. But we can do a lot to make it choose the right course and that by suitable changes in the terms of tenure of this class. What particular form these changes should take it is needless to repeat here as I have already written of them in my article: "The Ideal System of Land Tenure" published in Vol. 1, No. 4 of the Indian Journal of Economics, published by the University of Allahabad.

Allied to these are those religious mendicants and inmates of monasteries that have large landed estates assigned to them. There is no published statistical data, that I know of, and that could give us an idea of the property now held by big *mahants* of various *Panths* and *Piths*. But that it is considerable is beyond question. Most of these were intended for

purposes of education and the inculcation of high moral ends, and it is up to our various denominational leaders to see that the funds are applied to the purpose for which they were meant. As they are, the *mahants* and *mutwalis* look upon them as their personal estates. This should be ended as soon as possible. With the funds so secured we should be able to make not only existing residential universities of Benares and Aligarh independent, but to develop many others. A searching enquiry should be set on foot to find out the collective value of such trusts in the various provinces, and then to allocate them for the maintenance of the existing educational and other public utility institutions as well as to develop other such institution wherever and for whatever purposes needed. The Sikhs and the Musalmans have already begun to act in the right direction, the Hindus should also move in the matter.

Coming to our last category of beggars, vagrants, witches and wizards we may note the history of Poor Legislation in England. It divides itself into four periods :

(A) Until 1600 the State continued to confine its efforts to the suppression of pauperism leaving the care of the unfortunate and the incapable to other agencies.

(B) During the 2nd period, inaugurated by the Act of Elizabeth (1601) the parish authorities were charged with the duty of poor-relief. This Act was supplemented later on by the Settlement Acts and the imposition of the Workhouse Test (1713).

(C) In the latter part of the 18th century, however, this practice began to be felt as unnecessarily hard. The Gilbert Act (1782) charged the Guardian of the poor to find work for any one who applied for it and in the meantime to maintain him in his house at public expense. The consequences were unfortunate. People applied for work, who never intended to do it.

(D) The evils resulting from the Gilbert's Act were so great that in 1834 the Workhouse Test was re-established.

This brief history of English poor legislation will help us in avoiding the mistakes committed by English statesmen. But it cannot furnish a complete solution of the problem in India. In the first place the *Sadhu* and the *Fakir* are so intimately mixed up with religion in the Indian mind, that any abrupt attempt at legislation is sure to call forth a strong outburst of opposition. But that should not be a serious difficulty if we proceed cautiously sounding public opinion at each step and educating it in the process. The system of "suttee" was, after all, put down in the teeth of popular opposition.

As a first step towards legislation we must divide this class into four classes:

(1) "The unfortunate poor" persons who are willing to work, but who either cannot find work, or cannot find enough work, or in spite of hard labour cannot earn sufficient wages;
(2) "The Able-bodied Idlers" who will not work;
(3) "The Infirm" including the Aged, the Weak, and the young children; and
(4) Persons who have devoted themselves entirely to religion, and cannot think of earning their own bread.

All these classes will, of course, require different treatment. It is a pity that no statistics are available, but if one could judge by one's everyday experience in the streets, it would appear that the able-bodied idlers will constitute the highest proportion of the total number belonging to this class. I cannot lay down within the scope of this short essay any definite scheme to meet the difficulties presented by this class. I can only roughly indicate the lines on which we may proceed tentatively:

(*a*) The able-bodied idlers should be divided into two classes—married and unmarried. The married couple should

be allowed to live together, but the unmarried males and females should be kept apart and not allowed to marry, unless it is believed in the case of any two persons that they can be safely discharged from the workhouse. The workhouses should be under the District Board or the Taluq Board in rural areas and under the Municipal control in cities, and as far as possible managed on similar lines. All persons in the workhouse should be made to work. Roads, railways, canals, drainage, sanitation schemes and public buildings should provide enough work of an unskilled nature, and it is this kind of work that we must undertake whatever our schemes of rural reconstruction.

(*b*) Young persons should be placed in juvenile reformatories, where they should be brought up to some trade or handicraft. On reaching a certain age, say 18, they should be sent out in the world, with a little capital, to earn their own living.

(*c*) The aged and the weak, and otherwise incapable persons should be supported in Local Board and Municipal Infirmaries. In this case, the money required might, if possible, be raised by voluntary contributions, that is, by the organisation of the existing unorganised indiscriminate charity of the people and supplemented by contributions from the estates devoted to such purposes and now enjoyed as their private estates by the *mahants*, and *mutwalis*.

(*d*) True religious devotees should as far as possible be left free. The distinction would of course be very difficult to make. But if local persons of integrity were chosen to make the classification it would not be an impossible task. Moreover the number of such persons will be so small that fraud would be easily detected.

In laying down the foregoing proposals I have not been unconscious of the grave difficulties that must be surmounted before any practical steps can be taken, but in view of what is at stake I think it would be worthwhile incurring some little trouble. As a first step a census might at least be taken

with the necessary classifications, and then legislation necessary to facilitate the realisation of these ideas gone through.

The question of control and finance will also present difficulties. Personally I would place the management and control entirely in the hands of the municipality or the district board or the village panchayat as the case may be. The question of finance is more difficult, but local organisation of charity in the form of some sort of *Poor rate* combined with contributions mentioned above will seem to be the easiest mode.

Now to conclude. Owing to the lack of any statistical data I have only been able to deal with the subject in a vague manner. But I am convinced of (1) that the subject is an important one, and that with patience and hard work one could develop it considerably, making it more definite and of greater practical value, and (2) that in our schemes of reconstructing India a solution of this problem must form an important part.

DEVELOPMENT OF PERSIAN LITERATURE DURING THE TIME OF AKBAR

BY

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The reign of Timur, the "Scourge of Mankind," was undoubtedly the "Reign of Terror." The wholesale destruction and chaos wrought by his invasions were responsible for the decline of literary pursuits for a considerable time.

But Timur's rule was not an unmixed evil. History tells us that the ferocious conqueror and his descendants were equally lovers of learning and patrons of men of letters.

The last of this line, Sultan Husain Mirza, and his illustrious minister, Ali Sher, the patron of Jami, were themselves possessed of literary skill, and gave the most opportune encouragement to the learned. It is chiefly due to the stimulus given by these princes that we notice some eminent poets flourishing in the next period, *i.e.*, that of the Safawids.

Since the achievements of the Timurides in Persia do not form the theme of the present essay, we may now conveniently pass to the treatment of the literary activities carried on under the Timurides in India.

We know that Babar, fifth in descent from Timur, came to India in 1526, overthrew the so-called Pathan kingdom of Delhi and founded the great Mughal empire. But he did not live long to enjoy the fruits of his triumph, and on his death, which took place in 1530 A.D., his son, Humayun, ascended the throne. His right was, however, contended by the Afghans who drove him away to Persia in 1540. After varying fortune and long exile, he succeeded in regaining his lost

kingdom, but died in 1556. Humayun's eldest son, Akbar the Great, succeeded his father. Akbar's long reign, which extended over a period of fifty years (1556—1605), is remarkable in History for its wide conquests and judicious administration. He exercised his sway over a vast empire extending from Kabul to Bengal, and from Kashmir to Ahmednagar. The sense of general peace throughout the country and the growth of luxury in the mode of living gave rise to the cultivation and development of Fine Arts in the land. It is chiefly for this reason that no period in Muhammadan India is so rich in the production of literature as that just mentioned.

Now we shall discuss in detail the circumstances which brought about, in the words of Prof. Ethe, this "Indian summer" of Persian literature.

First, let us try to ascertain the extent to which Persian poetry and prose reached in Akbar's time. V. Smith enumerates the different forms of literature in this period and divides them into six heads: (1) Translations, which are seldom read now and of whose literary merit it is difficult to obtain a competent opinion, (2) Histories, which he regards as records of facts only, being valueless as literature, (3) Letters, (4) Verse, extremely numerous, (5) Books on Theology, and (6) Technical works. It seems unnecessary to give here a list of the works translated or originally composed under the direct patronage of Akbar or during his reign. The number of works, exceeding forty, clearly shows how great was Akbar's love for learning. These books written, with the exception of a few, in Persian, were mostly completed at the command of the Emperor himself. They consist of translations from Sanskrit, Hindi, Arabic, Turkish and Greek as well as of original works; and deal with subjects like History, Biography, Fiction, Mathematics, Physics, Astronomy, Philosophy, Medicine, Geography, Rhetoric and so on. I have considered it expedient to omit here the detailed account of various Kulliyats and Diwans produced during this period, since I will have to discuss them later on.

As regards purely Theological or Technical works of this period, mostly written independently of the court such as مدارج النبوة ، جذب القلوب ، اخبار الاخيار etc., I deem it out of place to discuss them in this short essay.

In this connection, it will be worth while to give, at some length, an account of the scholars and poets who were attached to the court of Akbar and wrote for him books, some of which are still extant and universally admired. It was, of course, their presence which graced his regime and immortalised his name. One cannot doubt that it was the stimulus given by this age, which later on manifested itself in the literary activities of the reigns of Jehangir and Shahjehan, till the Puritan Aurangzeb put a stop to the so-called Fine Arts prevalent at the court.

Now, Abul Fazl, the best and first-hand authority on the reign under consideration, gives a long list of the scholars of his time (numbering about 110) and classifies them into five groups.

As regards the poets or verifiers (قافيه سنجان), as Abul Fazl calls them, there is a large number of them belonging to the court. He mentions only a few distinguished ones, 59 being the actual number of these select "singers." Those who addressed their eulogies to the Great Mughal, but could not have access to the royal presence, were 16 in all, ظهوري ترشيزي and ملك قمي being the most important among them. According to خواجه نظام الدين احمد, the author of the طبقات اكبري, the number of scholars (theologians) and philosophers of Akbar's time exceeded one hundred, while that of poets reached eighty.

Al Badauni, in the third volume of his valuable history, which he has devoted to the treatment of literary activities of his time, furnishes us with the notices of about 70 ulemas and 160 poets, most of whom were foreigners and lived on the bounty of the king and his nobles. What a great Academy

of men of letters! So long as the account of Muhammadan India exists in the annals of the past, no student of history can ignore the name and works of scholars like شيخ مبارك ناگوری, father of ابوالفيض and ابوالفضل, and himself a genius of his age, شيخ عبدالحق محدث of Delhi, a great doctor of the Sunni sect, and a voluminous writer, شيخ يعقوب of Kashmir, pupil of the famous شيخ ابن حجر of Mecca and himself an imam in تفسير and حديث, ميرفتح الله شيرازي, the well-known philosopher, قاضی نظام بدخشي, an eminent متكلم - قاضی نورالله شوستري, the author of مجالس المومنين, صدرالصدور شيخ عبدالنبي of Sultanpur, مخدوم الملك عبدالله, سيدمحمد مير عدل and last, though not least, of all ملا عبدالقادر البدايوني, the uncompromising writer of منتخب التواريخ; or of poets like نظيري, عرفي, غزالي, فيضي, ميلي, شيري, ثناي, whose consummate art and sweet melody gave them a very high place in Persian literature.

تلك آثارنا تدل علينا ❋ فانظروا بعدنا الي الآثار

At this stage, the reader will be in a position to trace the causes which contributed to the development of this new epoch in the history of Persian literature.

While discussing literary problems one always realises that such problems do not, unlike a physical phenomenon, admit of being defined in terms of cause and effect. But so far as contemporaneous history and local conditions go to help us, we may be right in concluding that,

(1) The soil of India has always been favourable to the production of art and literature. The atmosphere of the country was reeking with literary taste, and it is a fact that the voice of the age found its utterance in the prose and poetry of the Mughal court. Originality—تازه گوئي—of expression (اسلوب ادا) is a chief characteristic of Indo-Persian poetry, which will be subsequently discussed.

(2) The sense of security and general peace gave rise to growth of luxury, which, in its turn, resulted in this "Indian summer" of Persian literature.

(3) Akbar and his nobles were all patrons of men of letters. They extended their generous support to exiled scholars and poets and thus succeeded in establishing a grand Academy of the best minds of the age. It is obvious that, in Asia, Art and Literature have always flourished under the direct patronage of Governments. India, we little need to add, was no exception to the rule. خزانهٔ عامره is full of instances of substantial rewards conferred on poets by their royal patrons. On occasions, it so happened that kings or their nobles ordered the mouth of their eulogist to be filled with pearls or his body to be weighed up with gold in the opposite scale.

It should be remembered, on the other hand, that the rival dynasty, that of the Safawids of Persia, was equally intent upon the propagation of learning and the encouragement of the learned. Kings, and even nobles, vied with each other in this respect, and this feeling obviously served as a great impetus to the cultivation of letters. علامهٔ شبلي is of opinion that, since Safawid rulers were themselves learned and held learning in esteem, and since Persia was, at that time, enjoying the fruits of peace and civilisation, literature, and especially poetry, naturally reached its climax in excellence and refinement. But I, with due deference to the learned شبلي, cannot agree with him in holding that the Safawid period was a successful period for light literature. On the contrary, I may be allowed to urge that no poet of the Safawid period, not even the great شفائي, ever commanded half the influence or reputation as فيضي, عرفي or صائب did. The comparative study of both the styles, Safawid and Mughal, and their relative importance should better be postponed to a suitable time. Yet it would be worth while to note the circumstances

which influenced the Safawid literature. Literature, especially poetry, achieved no progress under the Safawid Shahs, merely owing to lack of patronage, as Browne observes, not owing to lack of talents, because the Safawids devoted their energies to the propagation of Shia doctrine, the state religion of Persia, and the encouragement of Mullas. Besides this, they suppressed Sufism and Sufi literature, while they encouraged elegies addressed to the Imams (threnodies or مرثيه), in place of eulogies addressed to themselves (encomiums or قصيده). Thus disheartened and disappointed, hosts of poets flocked to the Mughal court for the sake of gaining admiration and material reward.

(4) Mughal emperors and nobles were, at the same time, great critics, and their apt criticism was, to a great extent, responsible for the refinement of ideas and originality of expression (لطافت تخييل, جدت اسلوب), so characteristic of Indo-Persian literature.

As this point has much to do with the present essay, I may be permitted to explain it at some length.

The Timurides, both of Persia and India, had a sound taste for literature. Babar and Humayun could compose fine verses, and maintained several poets, like آتشي of Kandahar, خواجه حسين of Merv, سيد علي جدائي of Tabrez, etc. The former, in his incomparable memoirs ترك بابري, has given notices of certain poets, with criticism on their style, in a way which even professional critics can hardly excel.

Humayun's son, Akbar, although illiterate, was an enthusiastic lover of literature and learning. It was he who formed an assembly of the learned (مكتب or Translation Department), and caused many translations and original works to be published. It was he who arranged for religious controversies at his court and himself acted as a judge. Every useful book was read in his presence and every discussion brought to his notice. Akbar was the first Timuride emperor who created the office of poet-laureate (ملك الشعراء) to which

غزالي, and, after Ghazali's death, فيضي, were appointed by the emperor himself.

As already pointed out, Akbar had a very refined taste for literature and composed good poetry. The following lines ascribed to him show how attractive was the melody of his verses :

دو شینه به کوئے میفروشاں * پیمانهٔ مے به زر خریدم
اکنون زخمار سر گرانم * زر دادم و درد سر خریدم
من بنگ نمي خورم بیارید * من چنگ نمي زنم نیارید

Abul Fazl tells us that once the following couplet was recited in the presence of the Emperor :

مسیحا یار و خضرش همرکاب و همعنان یوسف
فغاني آفتاب من بدین اعزاز مي آید

to which he at once retorted, "Had there been the word شهسوار in place of آفتاب, the phraseology of the line would have been more suitable."

Besides Akbar, his sons, سلیم and مراد, and other members of the royal family, were also cultured and were fond of men of culture.

But, above all, there were certain chiefs, who, besides liberally supporting scholars and wits of their time, gave them a sort of critical training which rendered their art more and more consummate. These were Abdur Rahim Khan-i-Khanan, Hakim Abul Fath of Gilan, Ali Quli Khan Khan-i-Zaman, Khan-i-Azam Kokaltash, Zafar Khan and Ghazi Khan. Most of them were furnished with princely establishment and held separate darbars.

It seems desirable to jot down a few lines concerning some of them and to show what efforts they made to elevate the standard of literature, especially poetry. The name of Abdur Rahim, Khan-i-Khanan, tops the list, and it is a fact that his appropriate suggestions as well as his generous

rewards were of greatest service to علم and علماء. His father Bairam, Khan-i-Khanan, too, was a good poet and has left his Persian and Turkish Diwans, which have now been published. Abdur Rahim, the illustrious son of Bairam, was equally learned, but more generous. He was master of Persian and Turkish and also well acquainted with Arabic and Sanskrit. He was thoroughly versed in the learning of his age, as well as in poetry and rhetoric. Of his works, the Persian translation of تزك بابري, a مثنوي on Astronomy, with one hemistich in Persian and the other in Sanskrit and a few odes and quatrains are extant. He had a vast library of his own, with rare manuscripts of every kind in it. The poets عرفي, نظيري, شكيبي, حياتي, نوعي, كفوي, بيروي, رسمي, and محوي were attached to his person and lived on his generosity. As already remarked, the instructive suggestions which he made from time to time kept the standard of poetry from becoming low. ملا عبدالباقي نهاوندي in the ماثر رحيمي (Abdur Rahim's biography) gives the following remark about the style of Urfi :

به اندك فرصتے به يمن تربيت و شاگردي و ملازمي اين داناے رموز (عبدالرحيم) پختگي تمام و ترقي مالاكلام در منظومانش بهم رسيد -

Next to Khan-i-Khanan, comes Hakim Abul Fath of Gilan, the great philosopher and physician of Akbar's court. He was a friend of Khan-i-Khanan and shared most of his good qualities. Abdul Baqi holds that تازه گوئي, which is a characteristic of Indo-Persian poetry, is the outcome of Abul Fath's mind, and that it was his training which introduced this novel factor into the poetry of the 16th century. He was the patron of حياتي of Gilan, عرفي of Shiraz, ثنائي of Mashhad, مرزا قلي ميلي and others. In a letter, addressed to عبدالرحيم خانخانان, he writes :

ملا عرفي و ملا حياتي بسيار ترقي كرده اند

Space will not allow us to attempt, at any length, an account of what Ali Quli Khan, Khan-i-Zaman, the patron of الفتي and غزالي, Khan-i-Azam Kokaltash, the patron of جعفري هروي, فهمي, مدامي, بدخشي, مقيمي سبزواري, Zafar Khan, on whose support كليم and صائب lived, and of whose patronage and training the former often boasts and, last of all, Ghazi Khan, Governor of Kandahar, himself a poet and patron of poetry, did in order to raise the standard of literature. These nobles, as already indicated, were possessed of literary skill and culture, and one is compelled to believe, as some critics have observed, that mere flattery could not be a fit recommendation for wits to secure their favour.

(5) مشاعره or poetic competition had become popular and this practice actuated by struggle for supremacy among rival poets, enlivened all literary activities.

As regards prose, it would suffice to add that most of the above factors, together with court requirements, combined to free it from the irregularities and shortcomings which characterised the prose-writings of the Timurides of Persia—characteristics of later prose and poetry—specially of Indo-Persian literature of the 16th century.

Let us now consider the striking features of the writings of متاخرين and the improvement they made on the existing style of their predecessors. We shall take poetry first.

Persian poetry can be roughly grouped into four distinct periods: (1) متقدمين, (2) early متوسطين, (3) later متوسطين, (4) متاخرين. The first begins from the time of رودكي and ends with فردوسي and اسدي, the second is represented by انوري خاقاني, نظامي, etc., the third is represented by سعدي and حافظ in Persia and خسرو in India, and the fourth begins from فغاني. The main characteristics of the متقدمين are simplicity of ideas as well as of language, rhetorical devices

(ترصيع, etc.), and verbosity. The period of early متوسطين is marked for lofty ideas, forceful diction, abnormal similes and metaphors. This period, so to say, is purely "classical," while the former is mainly "romantic." The period of later متوسطين, indeed, serves as a connecting link, which lies midway between the two periods—the period of متوسطين and that of متاخرين. It shares the beauties of both the styles to a moderate limit—Mutawassitin's loftiness of ideas intermixed with Mutaakhkhirin's subtlety of imagination. During the period of متاخرين, however, poetry becomes a puzzle and nothing more. These poets indulge in heights of imagination, complex similes and far-fetched metaphors and thus render poetry obscure and difficult to an ordinary reader. At this stage, poetry evidently loses its classical nature and becomes "modern" in character.

Here it should be kept in view that most orientalists regard مولانا جامي as the last classical poet of Persia. Prof. Browne and Prof. Shibli believe صائب to be the last, while some urge that it was حزين with whom the classical character of Persian poetry ends. But, seeing that the style of فغانی and his followers on one side, and that of the rival school of شرف جهان on the other, indicate an obvious contrast to the style of متوسطين, and that, from this period, "Persian literature becomes essentially modern in form, colour and temper," we may be justified in holding that the sixteenth century marks the close of Persian classical period. It is, however, with the last period that we have to deal here. What are the characteristics of the poetry of this period?

Critics hold that, up to the time of the تيموريه عجم, نازك خيالي or subtlety of imagination was the chief criterion of all those who composed poetry, but, since the Safawid period, معامله بندي (وقوعه گوئي, or the description of the incidents of a lover's life) became fashionable. The latter school was originated by مرزا شرف جهان of Qazwin, the minister of Shah

Tahmasp. Some trace it back to سعدي and خسرو, but the popularity it gained was due to the said شرف جهاں. ولي قائني and علي نقي كمره ,علي قلي ميلي ,وحشي يزدي belonged to this school of thought. It should also be remembered that this style did not gain ground in India, which, thanks to God, was thus saved from this unholy, and sometimes obscene, form of poetry. Unfortunately our Urdu poets انشا and جرات indulged in these absurdities, but the majority of poets remained aloof. To illustrate this point, the following lines will suffice:

نه آشنا و نه بیگانهٔ نمي دانم
که اختلاط چنیں راکسے چه نام کند
پس از عمرے چو بنشینم بصد تقریب در بزمش
کلام از مدعاے من کند تازود برخیزم
صد بار رنجه گشته ام و صلح کرده ام
کان مه خبر نداشته از صلح و جنگ من
با آنکه به پرسیدن ما آمده مردیم
کایاز که پرسید ره خانه مارا

The other noteworthy and equally popular school was that of فغاني of Shiraz. This line of thought was followed in Persia by شفائي and محتشم, and in India by عرفي and نظيري. It became so popular in the latter country that subsequent poetry, based on the same principle and represented by طالب كليم ,جلال اسير and afterwards by بيدل and ناصر علي, became a mass of obscure and far-fetched ideas; for these poets delighted in exaggerated forms of thought and extreme heights of imagination (مضمون آفريني و تخيئل).

Now, what were the chief features of Fughani's style?

(*a*) Fughani and his followers generally express an idea in a very roundabout way. This peculiar way of expression, as Shibli thinks, is due to an obscure metaphor

or a desire for brevity. For example, the poet, Naziri, wonders how his sweetheart, in spite of being a "delicate damsel," can be so "cruel" to her lover. He puts the idea in this way. -

کسے بہ قلب شبم ترکتاز مي آرد
که بر فراش قصب پاے در حنا خفتست

In a نعتیه panegyric, عرفي, emphasising his uniqueness among poets, says:

سایه من همچو من در ملك هستي امنت
سایه تو در عدم پیغمبر همتاے من

This very desire for brevity, misplaced as it is, sometimes becomes the source of that دقت پسندي which typifies the works of بیدل and ناصرعلي. One of them says:

کف پاے حجله نشین‌ما بخیال کرد کمین‌ما
پے آرزوے جبین ما زچراغ رنگ حنا طلب

Another writes:

زلکنت مي تپد نبض لب لعل گهر بارش
شهید انتظار جلوه خویش است گفتارش

The same line of thought is apparent in the writings of مومن and غالب, who were, at first, very fond of "طرزبیدل."

(*b*) Poets belonging to this school delighted in play upon words. They used an ambiguous word and then erected the whole construction on that insecure foundation, meaning only the more remote signification of the word in question. This evil broke out among the متاخرین who, although not very fond of figures of speech, took pride in inventing virgin ideas. Thus the word آب, which conveys different senses like water,

lustre, sharpness, etc., was used in connection with the edge of the sword, but, at the same time, the poet altered it for his own purpose to mean some liquid object, say, wine.

مستانه کشتگان تو هر سو فتاده اند
تیغ ترا مگر که به مے آب داده اند

Ghurbati writes :

دهان یار بامن دوش رمزے گفت پنهاني
که من سرچشمه آب حیاتم هیچ مي داني

Ghani says :

حسن سبزے به خط سبز مرا کرد اسیر
دام همرنگ زمین بود گرفتار شدم

If you remove the epithet سبز, which is taken in a metaphorical sense, the whole superstructure falls to the ground; for, in that case, the whole force of the word هم رنگ, which is the key-note of the idea of the couplet, is lost and the beauty of the pun destroyed. It is for this reason that such lines do not admit of being translated into a foreign tongue, and, if translated, become ludicrous.

Europeans often feel disgusted at this misdirected ingenuity, because they cannot appreciate the beauty of equivocal terms thus used.

(c) This school is noted for novel similes and refined metaphors. It is an admitted fact that similes and metaphors make the idea more clear. For instance, when describing a beautiful person, we say that his face is just like the sun or rather the sun itself. This mode of expression is more emphatic, vivid and brief.

متقدمین confined themselves to this form of similes and metaphors. متوسطین, especially نظامي and خاقاني, elaborated

these similes and introduced more complex ones. نظامی is not contented with comparing the lip of نوشابه with a ruby, but describes her speech as the removing of the seal from the (casket of) ruby. زیاده قوت سر بسته بکشاد بند. In the same way, he depicts the everyday occurrence, *i.e.*, the rising of the sun and the disappearance of the stars in a very peculiar manner, saying, کلیچه شد آن سیم گاورس وار. In the time of متاخرین, civilisation had grown more complex and requirements of social life had multiplied. They, therefore, looked down on the simple modes of expression with disdain and directed their energies towards abstracting and elaborating previous types of common speech. This desire reached its extreme during the time of بیدل شوکت بخاری و جلال اسیر, etc., and defeated its own purpose. The idea, instead of being clear and graphic, became more obscure and difficult, and the simile, thus elaborated, rather than the idea itself, came in the front.

To illustrate the novelty of similes used by متاخرین, the following examples would do :—

Naziri says :

دامن کشاں چو ابر بہ گلزار مي روہ
تا آب نرگس کہ و برق گیاہ کیست

Urfi :

بہ عرضہ دادن شوق و بہ آب شستن یاس
بدستیاري توفیق و رنگ دادن کار
بہ مردمي کہ بود هم طویلۂ عنقا
بہ محرمي کہ بود هم قبیلہ اسرار

Faizi :

آں نقش کہ دانیش نمونہ * کہنش زدہ لعل و اژ گونہ
تابش نبود بچشم بینا * کیں مے بگدازد آدمینا
هم پاشنہ ریش و هم کف آماس * چوں پاے نہم بدشت الماس

This faculty, if rightly directed, is of great service to literature. But, as already pointed out, it was misdirected, and poets like بيدل, غني, ناصرعلي, etc., were the deplorable examples of this energy exercised in the wrong direction. For instance, بيدل writes:

به مرغزاريكه نرگس اوكند نگاهے زكنج ابرو
زداغ خود همچو چشم آهو به ناز چشمك زند پلنگش

Ghani says: تادید سر برهنگي طفل اشك ما
دريا بدست موج كلاه حباب دوخت

(*d*) The poetry of Persia has become, in the words of Mr. Browne, stereotyped, both in form and matter for the last few centuries. Such is the case with language. The language became so pure and polished in the days of the متاخرين, that not a single word or phrase, which was used in educated societies in those days, has been denounced as obsolete. The refined taste of the متاخرين, so to say, foresaw the condition of the language, many centuries ahead.

This is a quality shared by all schools of poetry (or literature in general). But the followers of فغاني did more to improve the tongue. They invented new phrases and constructions and thus widened the sphere of Persian language. Besides this, now they could express the maximum of thought with the minimum of words. These new تراكيب are very common in the writings of poets like عرفي, فيضي, etc. To illustrate our point, a few instances may be quoted:

Urfi:

بهبرقع مه كنعاں كه بود حسن آباد
به حجله گاه زليخا كه بود يوسف زار
به بخل و عده تراش و قناعت عياش
بصدق تنگ معاش و خوش آمداحرار

به طائر ارني سنج بے اثر نغمه ❋ بلن تراني هم ذوق و عده ديدار

Faizi :

آن مركز دور هفت جدول ❋ گرداب پسين و موج اول
چابك قدم بساط افلاك ❋ و الا گهر محيط لولاك
مشعل نه پيشگاه اقرار ❋ آتش زن دودمان انكار
اثر عتاب برون ز دل هم اندك اندك

Naziri : به بديه آفريدن به بهانه ساز كردن

Some minor features of the poetry of متاخرين . Besides the characteristics peculiar to either of these two schools already discussed, there were some other minor features common to both.

Thus we find that language, as already shown, became very pure, refined and graceful and متاخرين can be rightly credited for this service to literature. Another striking phase of their works is that they, unlike the متقدمين and متوسطين, very seldom make use of Arabic expressions and quotations. This is, *prima facie*, due to the fact that, at this time, Persian poetry had emancipated itself from the bondage of Arab Government. Moreover, the writings of later poets are also free from the use of rhetorical devices, as compared to those of older writers, such as رشيد و طواط , عبدالواسع جبلي, etc. Kamal Ismail was the first to protest against this silly practice, and his example was followed by others.

Characteristics of Indo-Persian literature.—At this stage, we are in a position to consider the characteristics of Indo-Persian literature; especially poetry, produced in the 16th century. It is needless to add that Indian poets shared, in common with Persians, all the modes of style, enumerated under the head متاخرين .

But what were the characteristics peculiar to Indian poetry?

Poetry in India began with مسعود سعد سلمان, the Governor of the Punjab, in the reign of Ibrahim Shah of Ghazni. He died in 515—1122. He was a poet of great eminence and followed the style of عنصري in his Qasidas. His language was very polished and he is said to have compiled Diwans in Arabic, Persian and Hindi. After مسعود, comes the famous اميرخسرو. His brilliant style, graceful tone, subtle ideas and dignified language are admitted even by the most prejudiced Persian. But the essence of his poetry, as he himself acknowledges, is derived from the great Sadi.

خسرو سرمست اندر ساغر معني بريخت
باده از خمخانه سعدي که درشير از بود

Khusrau's friend, حسن of Delhi, was, to a great extent, indebted to اميرخسرو for the literary training he received in his company.

Next comes the period of the Mughal poets. "Critics profess to discover a certain originality" in the works of the poets of Mughal period.

This originality (تازه گوي), Abdul Baqi of Nahawand tells us, was the outcome of the suggestions and criticism made from time to time by Hakim Abul Fath. The Hakim and his friend, Khan-i-Khanan, as we have learnt, were profound scholars of refined taste and had established an Academy of wits and poets. Their opportune criticism and liberal patronage served as an impetus to the poets, who, at the same time, actuated by rival feelings, tried to contrive for them best channels of thought.

تازه گوی has been interpreted in different ways. Prof. Browne understands that "a certain originality" typified the works of these later poets. That is all! Shibli Nomani, on the other hand, is of opinion that it refers to the لطافت ادا and باريك خيالي (elegance of expression and subtlety of thought); but he does not discuss its nature at a reasonable length. I,

on my part, take it to mean جدت اسلوب, originality of expression or arrangement. To illustrate this point, I shall quote a few lines. The reader should keep in mind that, in certain cases, the main idea is not original, but the mode of expression is so novel that one cannot but marvel at it. This feature is almost wanting in the works of contemporaneous poets of Persia, the Safawid poets. For example, the idea, that patience turns out victorious in the long run, has no novelty in itself; but the form in which عرفي puts it is at once novel and attractive. He says:

ز خمها برداشتیم و فتحها کردیم لیک؛
هرگز از خون کسے رنگین نشد دامان ما

There is a moral maxim: "Do not despise a man in distress, for, perhaps, his heart may be the seat of Divine love." This idea has been expressed by نظیري in the following way:

نیازارم ز خود هرگز دلے را ✵ که مي ترسم درو جائے تو باشد

Urfi says: عنایت صمدي رد کفر مانکند
اگر کمال پذیرد صنم پرستي ما
منکر نشوي گر بغلط دم زنم از عشق
کین نشه مرا گر نبود باد گرے هست
مگو که نیست گنه گار تر ز من عرفي
که این حدیث گرانمایه لاف یکتائیست
آن رهروے که شاد بترك تعلق است
بت سنگ راه وبت شکني سنگ راه اوست
عمرم بگریه هاے هوس صرف شد کنون

Naziri: عمرے بتازه بایدم و وا گریستن

از کف نمي دهد دل آسان ربوده را ✵ دیدیم زوربازوے نا آزموده را
من درپے رهاي و او هردم از فریب ✵ از سر گره زند گره نا کشوده را
تا منفعل ز رنجش بیجانه بینمش ✵ مي آرم اعتراف گناه نبوده را

خوں تراچه قدر نظیري خموش باش
این بس که دعوي از طرف قاتل تو نیست
آمد براے صلح و در جنگ باز کرد
صلحے به مصلحت پے جنگ دراز کرد
گرچه میدانم قسم خوردن بجانیت خوب نیست
هم بجان تو که یادم نیست سوگندے دگر
مرا به ساده دلیهاے من توان بخشید
خطا نموده ام و چشم آفریں دارم

Ghazali : شورے شد و از خواب عدم چشم کشودیم
دیدیم که باقیست شب فتنه غنودیم

Subuhi : هیچ جاے نه نشستي که رقیبت نه نشست
جز دل من که تو جا کردي و او بیروں ماند

Maili : صد بار رنجه گشته ام و صلح کرده ام
کاں مه خبر نداشته از صلح و جنگ من

By this time, the reader must have had an idea of what تازہ گوئي implies. This ingenious arrangement of ideas was one of the salient features of the 16th century poets.

Another remarkable feature of Mughal poetry was the absence of that obscenity that typified the satirists of Persia. In Persia, respectable poets like شفائي, (who was held in esteem by Shah Abbas the Great, and whose writings on تصوف have gained much reputation), used to indulge in such indecent satires that modern critics are disgusted to reproduce. Such was the case with وحشي also. But thanks to the chaste and refined taste of India, this profane form of literature was not allowed to cross the Indian frontiers. Indo-Persian poets did, when persuaded by feelings of jealousy, sometimes, satirise one another; but their writings never passed beyond the limits of decency.

It is said about Faizi, that he refrained from the use of even the least indecent word in his poems, and about Urfi that the rudest term he could use against his adversary is نامنفعلے (shameless). Another more obscene reference (perhaps the only one), which I have come across in his *Kulliat*, is that fragment (قطعه) which runs as follows :—

منعدم گردد, منتقم گردد......etc.

The only satirist among the poets of Akbar's time was ملاشیري of the Punjab. His satires, however, were free from foul references. In a fragment he censures the heretical innovations of the emperor in a very humorous way:

شاه ما امسال دعواے نبوت کرده است
گر خدا خواهد پس از سالے خدا خواهد شدن

About a century after Akbar, نعمت خان عالي , a deplorable example of misplaced ingenuity, won notoriety for obscene poetry under a clever disguise; but we have nothing to do with that period.

Another important characteristic of Mughal poetry, ignored by all critics, is the sublimity of the standard of love. Unlike Persian poets of the Safawid rule, whose ideal was معامله بندي, or the description of the incident of actual worldly love, Indo-Persian poets had, as their criterion, spiritual love, or at least, innocent love. We shall discuss the nature of love (عشق) at some length and illustrate from the writings of Urfi, etc., that the ideal of even ordinary love is very sublime in the works of the Mughal poets.

Urfi: مي روي داغير و مي گوئي بيا عرفي تو هم
لطف فرمودي بروكين پاے را رفتار نيست

Comp. Naziri: مردم از شرمندگي تا چند باهر ناكسے
مردمت از دور بنمايند و گويم يار نيست

Urfi: از صيد به خون گشته مپرهيز كه صياد
آرائش فتراك و ركابش همه خونست

گر شرط دوستي نه شناسي به حسن شمع
اول محبت تو به پروانه خوشتر است
کسے به زمره ارباب دل ندارد راه
که تحفه ز نسیم بلا نمي آرد

Naziri: عشق عصیانست اگر مستور نیست
کشته جرم زباں مغفور نیست
شرم ما باد که مشهور جهانیم به عشق
نشدیم آتش و برقے بدیارے نزدیم

Besides معامله بندي and واسوخت, which were the chief products of Persian soil, there was, we must confess, another variety of poetry which never flourished in India. This was مرثیه or threnody, especially meant for the description of the disastrous fate of the martyrs of Karbala. The chief advocate of this form of literature was محتشم کاشي. No poet, before or after محتشم, could compete him. This variety, if properly cultivated, would have been of substantial help to literature.

After all, India, although it derived its inspiration from Persia, cannot be said to lag behind in any respect. On the contrary, one is wonderstruck when one reads the hostile remarks of V. Smith, against the literature produced in Hindustan. As it appears, Smith had no direct touch with the writings of Akbar's time. His judgment seems to have been based on hearsay or on translations of the works. In his Chapter on "Akbar's Art and Literature," he says that the verse, though very numerous, lacks in sentiments, and that most of the poets, Faizi included, prostitute the word, "love," to the service of "unholy passions." He condemns them as torturing words into all sorts of shape, (by which he perhaps means rhetorical devices), and concludes by saying that the "Indo-Persian works of Akbar's age possess little interest as monuments of literary art."

It is needless here to refute these silly and insolent remarks.

Blochmann, on the other hand, holds that, after امیر خسرو, Muhammedan India has seen no greater poet than فیضي and that ابوالفضل, too, stands unrivalled as a writer of prose (see Maasir-ul-umara also).

Prose and its development.—Last, but not the least, is the prose literature produced in India during the 16th century.

Before the Mongol invasion, Persian prose was generally simple and direct, and, as Prof. Browne observes, nothing could be more concise and compact than the early prose works. Foreign influences, favouring flattery and bombast, seem to have been uniformly bad. The same state of things continued during the time of the Timurides (of Persia). Historical works, written by Mongol and Timuride writers, unlike the histories by Arabs, which were graphic, concise, convincing and based on اسناد, are strikingly inferior in substance and style and overburdened with florid, verbose and flattering expressions.

Now, the sixteenth century "brought with it a new way of thinking," quite different from that prevalent in the days of the past.

Safawid scholars began, at this time, to pursue religious studies and write "critical" works on Theology. Most of the prose works of the Safawid rule deal with theological matter or religious controversy and we may omit them from our theme.

Mughal authors, on the other hand, compiled a large number of works, relating to history, biography, philosophy, medicine, rhetoric, and what not.

We shall briefly discuss the latter here.

We must remember that the first prose work of Muhammadan India deserving notice was the طبقات ناصري, written by قاضي مهناج سراج of گرگان in 1252. This valuable work

was dedicated to ناصرالدين محمود, who ruled Delhi from 1246—66. It deals with general history and is "remarkable for the accuracy of its contents and the elegance of its style."

The next prose literature is that produced by امير خسرو. But it is a pity that his prose-works, like خزائن الفتوح (a book on history) and اعجاز خسروي (on rhetoric), are encumbered, with "a number of meaningless figures," continuous synonyms and obscure phraseology. Their intrinsic beauty is, so to say, marred by the exaggerated language and pedantic display of rhetoric. The same tendency typified most of the writings of Akbar's period. The Mongol and Timuride influence was so strong that books like انشاے ابوالفضل, اکبر نامه, نجات الرشيد, سه نثر ظهوري, etc., were written in a style, which was, at the same time, verbose and florid. Unfortunately most of the books on history and other subjects reproduce the same echo.

But about the end of the 16th century, some foresighted writers, like ابوالفضل and عبدالقادر بدايوني, realised the error of their style and attempted to reform it. As a result, works like آئين اکبري and منتخب التواريخ, appeared and the former evils were, to a great extent, cured. It is to be regretted, however, that the reform was short-lived, and later writings seldom deviated from the old track. Now, the books last named, though digressions from the trodden path, were not similar in style. Still one may discover some points common to both, differing from the old mode of expression. Thus, "the new style," adopted by the abovenamed scholars, differed from the old one, in that

(i) it dispensed with the roundabout way of expression, and adopted a simple and direct style ;

(ii) it gave up the florid and bombastic phraseology, common among the Timuride writers ;

(iii) it denounced the use of rhetorical devices ;

(iv) it emphasised the lucid delineation of the main purport with force of diction and dignity of manner;

(v) it preferred pithy, concise and compact phraseology, and

(vi) it laid stress on detailed and analytic scrutiny of facts.

This is a brief survey of the features which characterised the prose and poetry produced in India under Akbar and the circumstances which led thereto.

HINDI DEPARTMENT

A NOTE ON THE MSS. OF SŪRSĀGAR

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Next to Rāmcharit Mānas of Tulsīdās (written after 1574 A.D.), Sūrsāgar of Sūrdās (finished before 1550) is regarded as the most important work in Hindi literature. Just as Mānas is based on the Vālmīkīya Rāmāyan, so Sūrsāgar is based on Bhāgwat, but neither of these two Hindi versions should be regarded as a mere translation of the respective Sanskrit work. Unlike Mānas, Sūrsāgar has not yet been critically edited.[1] The present note on the Mss. of Sūrsāgar may prove useful in collecting material for bringing out a critical edition of this most important work of Braj Bhāshā.

The following Mss. have been examined in this paper:

A. *Ramnagar Ms.:*[2] In the Library of the Maharaja of Benares.

B. *Sabhā Mss.:* Three Mss. at the Nāgari Prachārinī Sabhā Library, Benares.

C. *Lucknow Ms.:* A private copy in the possession of Lala Shyam Sundar Das Agarwal, Murgakhana, Jardkothi, Lucknow.

D. *Brindaban Ms.:* In the private library of Shri Radha Charan Goswami, Benimadhava, Brindaban.

E. *Benares Ms.:* In the possession of Lala Girdhardas, Panni Gali, Benares.

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[1] For published editions of Sūrsāgar see Appendix A.

[2] A complete copy also of this Ms. is said to exist in the same library. I could not see it, however. A few more incomplete Mss. of Sūrsāgar are also said to exist in the library.

F. *Bharatpur Ms.:* In the possession of Thakur Debi Singh, village Boroli Dahar, P. O. Pahari, Nizamat Dig, Bharatpur State.

The Mss. have been examined below in the order in which they are mentioned.

I. DESCRIPTION OF THE MSS.

A. Ramnagar Ms.

General description.—The Ms. is numbered "102 Bhakti." The main work is quite complete and is written in a very beautiful and legible hand. The Ms. opens with "Sūrsāgar Sārāvalī" which is a sort of summary of the work in verse, and is supposed to have been written by the poet himself. "Sārāvalī" is given in 48 leaves and is found incomplete here. When the main work begins, new paging is given and it continues up to Skandha 9. These first nine Skandhas are contained in 99 leaves. The first half of Skandha 10 is written in 528 leaves, the second half occupies 32 leaves, and Skandhas 11 and 12 take 5 leaves only. The three portions have been paged separately. The total number of leaves in the Ms. thus comes to 712.

Number of songs.—The number of songs in the first nine Skandhas is 213, 37, 10, 12, 5, 4, 8, 14 and 170 respectively. The total number of songs in the first nine Skandhas thus comes to 473. In the first half of Skandha 10, songs have been numbered more or less continuously up to leaf 334, but afterwards they have not been numbered at all. The Skandha is divided into 49 Adhyāyas. The first few Adhyāyas, where songs have been numbered, contain about 100 songs to an Adhyāya or 8 songs to a leaf. The number of songs in the first half of Skandha 10 may, therefore, roughly be taken to be 4,500 ($49 \times 100 = 4{,}900$; $528 \times 8 = 4{,}224$). There is great likelihood of the actual number being much less than the estimated number.

The second half of Skandha 10 also does not give the number of songs. In the editor's preface to the Bombay edition of Sūrsāgar it is mentioned that the second half of Skandha 10, and Skandhas 11 and 12 were based on the Ramnagar Ms. The Bombay edition has got 138 songs in the second half of Skandha 10. This, therefore, may be taken to be the number in the original also. The inference is corroborated by the fact that the number of songs in Skandhas 11 and 12 of the Ms. is actually equal to that found in the Bombay edition. The number is 6 and 5 respectively.

If the rough estimate about the number of songs in the first half of Skandha 10 is taken as reliable, the total number of songs in the Ms. would be slightly over 5,000.

Date of transcription.—The date of transcription is given at four different places in the body of the Ms. The colophons mentioning dates run as follows:

1. End of Skandha 9:—

"इतिश्री भागवते महापुराणे सूरदास कृते नवम स्कंध समाप्तं ॥ शुभमस्तु संवत ॥ १८९७ ॥ वैसाष कृष्ण द्वीतीयायां ॥ मंद वासरे ॥०॥ लि० कन्हैयालाल ॥०॥"

2. End of the first half of Skandha 10:—

"इतिश्री सूरसागर दसम पूर्वार्द्धं समाप्तः ॥ शुभमस्तु संवत १८९७ भादो कृष्ण द्वितीयायां ॥ लि० सजीवनलाल साकीन वडी पिअरी ॥१॥ श्री० श्री० श्री०"

3. End of the second half of Skandha 10:—

"इतिश्री भागवते महापुराने सूरदास कृत दसम असकंध नवे अधा [1] श्रीभागवते सम्पूर्ण ॥ संवत १८९७ ॥ फाल्गुन कृष्ण पंचम्यां ॥२॥

4. End of Skandha 12:—

"इतिश्री भागवते सूरकृत संपूर्न ॥ संवत १८९७ ॥ भाद्रशुक्ल अष्टम्यां ॥

It is, of course, apparent from the above quotations that the Ms. was written in 1840 A.D. and it is, therefore, 85 years old. Almost a whole year was taken in writing the Ms. It was started most probably in the beginning of Samvat 1897. The first nine Skandhas were finished on Vaishākha Krishṇa 2.

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[1] Both in the Bhāgwat and the Sūrsāgar, Skandha 10 is divided into 90 Adhyāyas. "नवे अधा" therefore stands for नव्वे अध्याय।

The first half of Skandha 10, which is the major portion of the book, was finished on Bhādrapada Krishṇa 2, and took exactly four months to write. Skandhas 11 and 12 were taken up then and the book, with the exception of the second half of Skandha 10, was finished in the same month on Shukla 8. It appears that the writing of the second half of Skandha 10 was postponed for some reason. It was finished on Phālguna Krishṇa 5, *i.e.*, about four months and a half later.

The handwriting corroborates the statement that the first nine Skandhas and the first half of Skandha 10 were written by different individuals. Both the scribes appear to be more or less ignorant of the Sanskrit language, the latter writer is slightly better though.

B. Sabha Mss.

There are three Mss. of Sūrsāgar in the library of the Nāgarī Prachārinī Sabhā, Benares.

Ms. No. 1.—This copy is in good condition and is written in a legible hand, but 101 leaves in the beginning of Skandha 10 are missing. The end of the book also suggests that it is incomplete. It is mentioned in the book that it was written for the study of one Raja Guman Singh. The total number of leaves is 982.

The number of songs in each Skandha is as follows:—249, 48, 17, 12, 7, 4, 9, 14, 164, 3,296, 99, 4. The total of the numbers would thus come to 3,923.

In the beginning of Skandha 12, on leaf number 878, there is a note about the date of transcription which runs as follows:—"काति क्रस्न १० गुरुवासरे सँवत १९१७ अथ द्वादशा स्कंदः ॥" The Ms. was, therefore, written in 1860 A.D., and is only 65 years old.

Ms. No. 2.—This Ms. is very carefully written and is in a very beautiful hand, but it also is incomplete. It has got only the first nine Skandhas and even here some portions are

most probably missing. The number of leaves is 263 and that of total songs 504. The colophon runs as follows:—"इति नौम स्कंध समाप्त ॥ शुभं भूयात् ॥ लिखितमिदं पुस्तकं ॥ राजा सुवा सिंहस्य पठनार्थं ॥ संवत् १९०९ ॥ श्रीराम". The Ms. was thus transcribed in 1852 A.D. and is 8 years older than the previous Ms. The name of the scribe is not mentioned.

Ms. No. 3.—The Ms. is in two parts and contains the first half of Skandha 10 only. It is incorrect and incomplete. The first 10 leaves are missing. The total number of leaves is 501. The Ms. originally belonged to the library of Bhāratēndu Harishchandra. The first half of Skandha 10 in the Bombay edition of Sūrsāgar is based upon this Ms.

C. Lucknow Ms.

General description.—Though older than all the Mss. mentioned above, it is in excellent condition. It is written on old hand-made white paper of 12″ × 8″ size. Every page contains about 20 lines in a very beautiful hand. Skandhas 11 and 12 are not to be found in the Ms., but they appear to have been left out knowingly as the book has been ceremoniously finished after Skandha 10. In one sense the Ms. cannot be said to be incomplete, therefore.[1] The first nine Skandhas have got 166 leaves. Skandha 10 has got 665 leaves, the numbering having been started afresh. The total number of leaves thus comes to 831.

Number of songs.—The number of songs also is mentioned separately in the first nine Skandhas and Skandha 10. They have 524 and 3,813 songs respectively. The total number of songs thus comes to 4,337.

[1] The absence of Skandhas 11 and 12 does not take away the importance of this Ms. to any appreciable degree. These Skandhas are the most unimportant in Sūrsāgar. Other existing Mss. usually give 10 or 12 songs in these Skandhas. It may be remembered that the first half of Skandha 10 is the most important portion in Sūrsāgar. Even the first nine Skandhas and the second half of Skandha 10 are more or less supplementary.

Date of transcription.—The colophon, which gives the date very clearly, runs as follows:—"संवत् १८६६ शाके १७३१ ज्येष्ठ शुक्ला ५ पंचम्यां भृगुवासरे ॥ लेषक त्रिपाठी लक्ष्मीनारायण लाला साहब मोदी गंगारामजी पठनार्थं ॥ श्री ॥ कल्याणमस्तु ॥ श्री ॥ श्री ॥......"
The book was, therefore, transcribed in 1809 A.D., and is therefore 116 years old.

Special features.—The Ms. is remarkable for certain special features. The most unique thing about the Ms. is that it is profusely illustrated. It has got 155 excellent coloured paintings scattered throughout the book. The paintings are really high class and much care, workmanship and labour appears to have been spent on them. Sometimes small paintings are found by the side of songs on the same page.

The second special feature of the Ms. is that a list of songs is given at the beginning in 55 leaves. The beginning of all the songs is found in the list. The last portion of this list was somehow lost and was replaced afterwards. This portion is written in Persian characters. A list of the paintings is also attached.

D. Brindaban Ms.

General description.—The Ms. appears to be old but is in good condition. It is numbered as श्रेणी १, वर्ग १, अंक २५. It has got Skandha 10 only and even there the number of songs is limited.

Number of songs.—The number of songs is 1,252. It should be remembered that the usual number of songs found in Skandha 10 is about 3,500.

Date of transcription.—The colophon runs as follows:—"इतिश्री सूरशागर वृज विलास लीला संपूरणं सुभं भूयात् ॥ संवत १८८६ ॥ फाल्गुण वदी पंदरस ॥ वार मङ्गल ॥ लिषतं जगन्नाथ ॥ श्रीगणेशायनमः ॥"
The Ms. was, therefore, written in 1832 A.D., and is 93 years old.

E. Benares Ms. [1]

General description.—It is a very incomplete Ms. of Sūrsagār. A small portion of the first half of Skandha 10, the second half of Skandha 10 and Skandhas 11 and 12 only are found in the Ms. now. [2] The first nine Skandhas are missing and so is the major portion of the first half of Skandha 10. Even in the remaining portion of Skandha 10, 14 leaves are missing at various places. The Ms. opens with leaf number 398. The last leaf of the first half of Skandha 10 is numbered 602. Thus only 204 leaves of the first half of Skandha 10 exist now and 397 leaves are missing. The second half of Skandha 10 and Skandhas 11 and 12 are found in 46 leaves, the second half of Skandha 10 taking 40 leaves and the remaining two Skandhas three leaves each. The total number of existing leaves is therefore 250 only.

Number of songs.—Songs have not been numbered regularly in the Ms. The estimated number of songs in the existing portion of the Ms. is approximately 1,500.[3] Skandhas 11 and 12 have got 4 songs in each of them.

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[1] I am obliged to my student Mr. Lalta Prasad Shukla, B.A., for a full description of this Ms.

[2] The Ms. was complete when the Bombay edition was first brought out (see the Publisher's Preface to the said edition). Lala Girdhar Das, in whose possession the Ms. is at present, also says that the Ms. was complete and that the first two parts of the Ms. have been lost.

[3] The first song on the first existing leaf of the Ms. is number 2,153 on page 396 of the Bombay edition (published in Samvat 1980). From this page onwards, the total number of songs in the edition comes to 1,491 (1,342+138+6+5=1,491). A similar number of songs may, therefore, roughly be taken to exist in the Ms. also. It may be stated here that the end of the first half of Skandha 10 and both the beginning and the end of the second half of Skandha 10 and Skandhas 11 and 12 are almost the same as found in the Bombay edition.

Date of transcription.—The date of transcription is given at two different places in the Ms. The colophons run as follows :—

1. End of the first half of Skandha 10—

   " इतिश्री सूरसागर दसम स्कंध पूर्वार्द्ध समाप्तः ॥०॥
   ॥ श्रीसंमत ॥ १६०१ ॥ चैत्र शुक्ल ॥ ६ ॥ मंद । वासरे ॥ "

2. End of Skandha 12—

   " इति श्री भागवते महापुराणे द्वादशस्कंधे
   श्री भागवत सूरदासकृत समाप्तम् ॥ दोहा ॥
   सूर सुसागर सूरकृत गुनगन सागर स्याम ॥
   गिरिधर सागर प्रेम के लिषि जै मंगल नामा (म) ॥ १ ॥
   वारानसि सुर सरि निकट मान मंदिल असनाम ॥
   संग सजीवन लाल को सुंदर सुषद मुकाम ॥ २ ॥
   कविताई रस दुगुन सत अधिका एक सत दोय ॥
   अम्मावस वैशाष की भौमवार शुभ होय ॥ ३ ॥

The Ms. was therefore finished in Samvat 1902 (1800+102) or 1845 A.D., and is therefore only 80 years old.

It may be noted down that the scribe 'सजीवनलाल' is the same who transcribed at least the first half of Skandha 10 of the Ramnagar Ms. in 1840. He, however, mentions a different place of residence in the Ramnagar Ms.

F. Bharatpur Ms.[1]

General description.—The Ms. looks old and is not in good condition. The number of leaves is 436. Leaf number 20 is missing, otherwise the Ms. is complete. The numbers on leaves appear to have been written by a later hand.

Number of songs.—The number of songs in the 12 Skandhas is 208, 38, 10, 12, 4, 4, 8, 14, 185, 1,738, 3 and 4 respectively. The total number of songs would therefore come to 2,228. The numbering begins afresh from Skandha 10 and

[1] I am indebted to Pandit Ogha Raj, Head Teacher, P. O. Pahari, Bharatpur State, for sending a full description of the Ms.

continues up to the end of Skandha 12. The first and the second half of Skandha 10 have not been separated.

Date of transcription.—The colophon runs as follows:—"इतिश्री भागवते महापुराणे सूरदास कृतो द्वादशस्कंधः समाप्तः ॥ १२ ॥ इति संपूर्णम् ॥ संवत् १७९८ श्रावण मासे कृष्णे पक्षे पंचम्यां चंद्रः :शुभं भूयात् ॥ कल्याणमस्तु ॥ श्री ॥ श्री ॥ श्री ॥ श्री ॥ श्री ॥ श्री ॥ श्री ॥ श्री ॥ श्री ॥. It may be noted here that the first three figures of the Samvat, *viz.*, 179, are written in red ink as is found at some places in the numbering of songs, while the last figure 8 is written in black ink and resembles the numbering found on the leaves. The Ms. was thus written in 1741 A.D., and is 184 years old. This is the oldest Ms. of Sūrsāgar found as yet.

II. COMPARISON OF THE MSS.

As Brindaban and Benares Mss. are fragmentary, I have not taken them into consideration here. Of the three Sabhā Mss. I have taken into account No. 1 only, as this is the only complete Ms. there. Facts from the Bombay edition have also been included for the sake of comparison.

Readings.—As a typical specimen, I am giving below the first song of Skandha I, as found in these complete Mss. and the Bombay edition.

A. Ramnagar Ms.:—

चरन कमल वंदौं हरि राइ ॥
जाकी कृपा पंगु गिरि लंघै अंधे को सव कछु दरसाइ ॥
वहिरौ सुनै मूक पुनि वोलै रंक चलै सिर छत्र धराइ ॥
सूरदास स्वामी करुनामय वारवार वंदौं तिहि पाइ ॥

B. Sabhā Ms., No. 1 :—

चरन कमल वंदौ हरिराय़ ॥ [1]
जाकी क्रपा पंगू गिरि लंघै अंधे कों सब कछु दरसाय़ ॥
वहरा सुनै गूंग पुनि वोलै रंक चलै सिर छत्र दुराय़ ॥
सूरदास स्वामी करुनामय़ बारबार वंदौ तिहि पाय़ ॥

[1] 'य़.' has been written to distinguish it from प. प is very often written as 'य.' Further 'व.' is written to distinguish it from ब which is usually written as 'व'.

C. Lucknow Ms.:—

चरन कवल वंदौ हरिराय ॥
जाकी कृपा पंगु गिरि लंघै अंधे कूं सब कुछ दरसाय ॥
वहरा सुनैं गुंग पुन वोलै रंक चलै सिर छत्र दुराय ॥
सूरदास स्वामी करुणामय वारवार वंदौ तिहि पाय ॥

D. Bharatpur Ms. :—

चरण कमल वंदो हरिराई ॥
जाकी कृपा पंगु गिरि लघै आधे को सब कछु दरसाई ॥
बहरा सुनै मूक पुनि बोलै रंक चलै सिर छत्र धराई ॥
सूरदास स्वामी करुणामय बारबार बंदो तिहि पाई ॥

Bombay edition :—

चरण कमल बंदौं हरि राई ॥
जाकी कृपा पंगु गिरि लंघै अंधे को सब कछु दरशाई ॥
बहिरो सुनै मूक पुनि बोलै रंक चलै शिर छत्र धराई ॥
सूरदास स्वामी करुणामय बारबार बन्दौं तेहि पांई ॥

In the following table, attention is drawn to the different readings of the same word of the song as found in the Mss. and the edition.

A. Ramnagar Ms.	B. Sabhā Ms., No. 1.	C. Lucknow Ms.	D. Bharatpur Ms.	Bombay edition.
चरन	चरन	चरन	चरण	चरण
कमल	कमल	कवल	कमल	कमल
वंदों	वंदौ	वंदौ	वंदो	बंदौं
राइ	राय्	राय	राई	राई
कृपा	क्रपा	कृपा	कृपा	कृपा
पंगु	पंगू	पंगु	पंगु	पंगु
अंधे	अंधे	अंधे	आधे	अंधे
को	कों	कूं	को	को
कछु	कछु	कुछ	कछु	कछु
दरसाइ	दरसाय्	दरसाय	दरसाई	दरशाई
वहिरौ	वहरा	वहरा	बहरा	बहिरो
मूक	गूंग	गुंग	मूक	मूक
पुनि	पुनि	पुन	पुनि	पुनि
सिर	सिर	सिर	सिर	शिर

A. Ramnagar Ms.	B. Sabhā Ms., No. 1.	C. Lucknow Ms.	D. Bharatpur Ms.	Bombay edition.
धराइ	डुराय्	दुराय	धराई	धराई
करुनामय	करुनामय्	करुणामय	करुणामय	करुणामय
तिहि	तिहि	तिहि	तिहि	तेहि
पाइ	पाय्	पाय	पाई	पांई

This comparison of the forms of these words leads us to certain conclusions :

1. There appears to be some similarity in the readings of Ramnagar and Bharatpur Mss. Mark the last words of every line, *viz.*, राइ, दरसाइ, धराइ, and पाइ. Also mark वंदो, को and मूक.

2. Ramnagar Ms. has ordinarily got standard readings. The forms in the Bharatpur Ms. appear a bit more Sanskritized. Note the words चरण and करुणामय. There are certain peculiar forms in the Bharatpur Ms. however, *e.g.*, आधे and बहरा.

3. Sabhā and Lucknow Mss. belong to a class of their own. Mark the words वंदौं, वहरा, कों or कूं and गूंग or गुंग. Also note the last words of every line, *viz.*, राय, दरसाय, डुराय or दुराय and पाय.

4. Some of the words in the Sabhā Ms. are unique. These suggest that this version of the Sūrsāgar was at some time taken down from the mouth of a singer. Mark the forms—क्रपा, पंगू, कों, गूंग and डुराय्. There is no attempt towards Sanskritizing the forms in this Ms. Note the words चरन, सिर and करुनामय.

5. Lucknow Ms., too, has got certain peculiar readings, but the reason is not clear. Note the words कवल, कूं, कुछ, गुंग, पुन, दुराय. The form करुणामय is found here but not चरण and शिर.

6. Readings in the Bombay edition belong to Ramnagar-Bharatpur class. In the Sanskritization of the words and the forms of the last words, the readings are nearer to the Bharatpur Ms. Mark the forms राई, दरशाई, धराई and पाई. Also note चरण, दरशाई, शिर, and करुणामय ।

Number of songs.—The following table about the number of songs in each Skandha, as found in the different Mss. and the edition, may be found instructive.

Skandhas.	A. Ramnagar Ms.	B. Sabhā Ms., No. 1.	C. Lucknow Ms.	D. Bharatpur Ms.	Bombay edition.
I	213	249	265	208	212
II	37	48	38	38	38
III	10	17	13	10	18
IV	12	12	13	12	12
V	5	7	7	4	4
VI	4	4	4	4	4
VII	8	9	7	8	8
VIII	14	14	16	14	14
IX	170	164	161	185	170
X	4,500 (approximate)	3,296	3,813	1,738	3,627
XI	6	99	...	3	6
XII	5	4	...	4	5
Total	4,984	3,923	4,337	2,228	4,118

1. Skandha 10 has apparently got the largest number of songs—far above even to the combined total of songs in all the other Skandhas.

2. Next, though far below Skandha 10, come Skandhas 1, 9 and 2 respectively. The other Skandhas appear to be very unimportant, at least from the view of the number of songs.

3. Skandha 1 of the Lucknow Ms., Skandha 9 of the Bharatpur Ms. and Skandhas 2 and 11 of the Sabhā Ms. have got a larger number of songs in them. Otherwise the number of songs in all the Skandhas, except Skandha 10, is almost equal in all the Mss. as well as in the printed edition. The slight deviations from the normal may be due to the confusion in marking the number of songs. It is just possible that there may be a few additional songs in some of the Mss.

4. As to Skandha 10, Ramnagar and Bharatpur Mss. are on two extremes. The figures of the Ramnagar Ms. are approximate and hence not very reliable. Bharatpur Ms. has certainly got a very small number of songs. The other two Mss., along with the printed edition, are more or less uniform in their figures about this Skandha.

5. Ramnagar Ms. has got almost the same number of songs in all the Skandhas except in Skandha 10 as we have got in the Bombay edition. But from this fact we cannot draw any inference as to the number of songs in Skandha 10 of the Ramnagar Ms. as Skandha 10 and Skandhas 1—9 of the Bombay edition are based on different Mss.

Dates of transcription.—Mention of the dates of transcription of the different Mss. at one place would prove convenient.

		Samvat.	Christian era.	No. of years up to 1925.
A.	Ramnagar Ms.	1897	1840	85
B.	Sabhā Ms., No. 1	1917	1860	65
	,, ,, No. 2	1909	1852	73
C.	Lucknow Ms.	1866	1809	116
D.	Brindaban Ms.	1889	1832	93
E.	Benares Ms.	1902	1845	80
F.	Bharatpur Ms.	1798	1741	184

Bharatpur Ms. is apparently the oldest of the Mss. Next comes the Lucknow Ms. All the other Mss. were written within the last hundred years. Sabhā Ms. is the latest of the lot.

III. CONCLUSIONS.

1. Of the eight Mss. examined in these pages, Ramnagar and Lucknow Mss. are the best and the most complete. Further, they are the representatives of two different classes. Sabhā Ms. holds the third place. Bharatpur Ms. is the oldest

of the Mss. and it has therefore got an importance of its own. The other four Mss. are incomplete and are not important in any way.

2. Except the Bharatpur Ms. which is 184 years old, all the other Mss. were transcribed within the last 125 years. It may be remembered in this connection that the original Sūrsāgar was composed just before 1550 or about 375 years back. It is therefore possible to find Mss. bearing an earlier date of transcription. Such Mss., if found, should naturally be more reliable specially from the point of view of readings.

3. In none of the Mss., the number of songs is more than 5,000—rather it is nearer to 4,000. The existing Mss. do not appear to be fragmentary. Consequently the number of songs in Sūrsāgar should be taken to be between 4,000 and 5,000, and not one lac and a quarter as the tradition says.

4. Skandha 10 is by far the most important portion in the Sūrsagār, both from the point of view of the subject-matter as well as the volume. It appears that the original idea of the poet was to compose Skandha 10 only, and he perhaps did compose it first. Stories of the other Skandhas appear to have been added afterwards to give the book a complete form as a translation of the Bhāgawat. It may be noted down that it is only in Skandha 10 of the Bhāgawat that the life of Krishna is described. The other Skandhas in main deal with the other incarnations of Vishnu. Sūrdās was a devotee of Krishṇa form of Vishṇu.

5. The small number of songs in the other Skandhas apparently suggests the idea that they may be incomplete. But by a comparative study of the Sūrsāgar and the Bhāgawat, I have come to the conclusion that the fact is not so. Almost all the topics found in these Skandhas in the Bhāgawat are found, though briefly, in the Sūrsāgar also. The number of songs in these Skandhas is therefore knowingly small.

APPENDIX A

PRINTED EDITIONS OF SŪRSĀGAR

1. Bombay edition

The only edition of Sūrsāgar worth the name is the one edited by Shri Radha Krishna Das and published by Venkateshwar Press, Bombay (First edition, Samvat 1953; last edition, Samvat 1980). It has got a preface, life of the poet and the contents.

The editor mentions in the preface that the edition is based upon the following Mss:—

1. *Skandhas 1—9:* A Ms. with B. Ramdin Singh, Bankipur. It must have been very much similar to the Ramnagar Ms.

2. *Skandha 10, first half:* A Ms. found in the library of Bharatendu Harishchandra. This Ms. is now in the library of the Nāgarī Prachārinī Sabhā, Benares, and has been described above (see Sabhā Ms. No. 3).

3. *Skandha 10, second half, and Skandhas 11 and 12:* A Ms. taken from the library of the Maharaja of Benares. (Most probably Ramnagar Ms.)

The publishers mention in their preface that an appendix, containing (1) corrections, (2) different readings, and (3) new songs, was sent by the editor to them when the book was already in press. It was prepared by the editor on the basis of a complete copy of Sūrsāgar lent by Lala Girdhardas, proprietor, Janimal Khanchand kī Kothi, Benares.

This appendix was not added to the first edition, nor has it been utilized in the last edition. Most probably the publishers lost it. This Ms. on the basis of which the appendix was prepared is the same which is described as Benares Ms. It is no more complete, a major portion of it having been lost by the owner.

The publishers mention the existence of another Ms. with Shri 108 Goswami Shri Balkrishna Lal, Maharaj Kākarōlī (Mewar). This copy was supposed to have the traditional 'Sawā lākha pada.' The Maharaja promised to lend the said copy to the publishers but the

opportunity was not utilized. Each portion being individually based on a single Ms., the edition is not very reliable from the point of view of readings. The number of songs in the different Skandhas has been mentioned above.

2. Lucknow edition.

It was published by the Newal Kishore Press. I have seen the fifth edition which is dated October, 1882 A.D. There is no preface, introduction or even contents of the book.

It is a sort of selection from Sūrsāgar and is divided into three parts, *viz.*, (1) Sārāvalī (2) Nityakīrtana and (3) Rāga-kalpa-druma.

1. *Sārāvalī:* It is almost the same as found in the Bombay edition. It is a sort of a list of contents in verse and is supposed to have been written by the poet himself.

2. *Nityakīrtana:* It is a selection of songs from Sūrsāgar meant for daily singing, and arranged according to various Rāgas and Rāginīs.

3. *Rāga-kalpa-druma:* This selection of songs has been taken from the first half of Skandha 10 only and is arranged according to the different episodes or "līlās" as mentioned in the Bhāgawat.

The Lucknow edition is said to be based on an earlier edition of Rāga-kalpa-druma published by Bangabasi Press, Calcutta. I have not seen this edition.

APPENDIX B

The following is a list of places where some more Mss. of Sūrsāgar are likely to be found. I have not been able to trace or examine them.

1. Skandhas 1—9 of the Bombay edition are based on a Ms. which was in the possession of Babu Ramdin Singh, Bankipur, Patna.

2. Publishers' preface to the Bombay edition mentions that a complete Ms. of Sūrsāgar is in the possession of Shri 108 Goswami Shri Balkrishna Lal, chief of Kākrōlī, (Shri Nathdwara, Mewar).

Search reports of the Nāgari Prachārinī Sabhā, Benares, mention the following new Mss :

3. One Ms. at the State Library, Bijawar; number of leaves 149, which shows that the Ms. is very incomplete (1906—8 ; 244C).

4. Three Mss. at the State Library, Datia ; one is dated 1816 A.D., the other two are undated (1906—8 ; 244 C).

5. Skandha 10 ; commentary ; number of leaves 101 ; place of deposit, Lala Debi Prasad, Mutasaddi, Chhattrapur (1906—8 ; 244 D).

6. Another Ms. is mentioned in the report of 1904 ; 142 but no address is mentioned. The date of transcription is given as 1796 to 1815.

Report of the existence of Mss. at the following places has also been received by me :[1]

7. Jodhpur, State Library—two Mss.

8. Jaipur, State Library.

9. Jaipur, Mohalla Brahmapura, one copy with a gentleman there.

10. Two copies of the Bharatpur Ms. are said to be in the library of Swami Brahmanath, Etawah.

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[1] Pandit Gauri Shankar Hirachand Ojha saw several Mss. of Sūrsāgar at Udaipur with some of the Sardars, who are all dead now. I have not been able to trace these Mss.

Mss. of Sūrsāgar are likely to be found in the temple libraries at Mathura, Brindaban and Gokul. My personal attempt at Gokul, the centre of the Vallabha Sampradaya, did not bring any fruitful result.

It is very widely believed that there is a Ms. of Sūrsāgar with a Jat in village Kānwar, near Kosi Station in Muttra District. On full personal investigation I came to know that no Ms. of Sūrsāgar exists in that village.